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Simulation of Oil Slick Transport in Great Lakes Connecting Channels

User's Manual for the Lake–River Oil Spill Simulation Model

Hung Tao Shen, Poojitha D. Yapa and Mark E. Petroski

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U.S. Army Corps of Engineers
Cold Regions Research & Engineering Laboratory

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Prepared for
OFFICE OF THE CHIEF OF ENGINEERS

PREFACE

This report was prepared by Hung Tao Shen, Professor of Civil and Environmental Engineering; Poojitha D. Yapa, Assistant Professor of Civil and Environmental Engineering; and Mark E. Petroski, graduate student, Clarkson University. The study was supported by the U.S. Army Corps of Engineers under Contract No. DACA33-85-C-0001. Steven F. Daly and Michael Ferrick of the U.S. Army Cold Regions Research and Engineering Laboratory are the contracting officer's technical representatives. The writers thank them, as well as Daniel Thompson and Donald Williams of the U.S. Army Engineer District, Detroit, for their cooperation and assistance throughout the study period.

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This report is one of a series of reports on numerical simulation of oil slicks in inland waterways. The series coordinator is Steven F. Daly, CRREL.

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HUNG TAO SHEN, POOJITHA D. YAPA AND MARK E. PETROSKI

INTRODUCTION

The growing concern over the possible impacts of oil spills on aquatic environments has led to the development of a large number of computer models for simulating the transport and spreading of oil slicks in surface water bodies. Almost all of these models were developed for coastal environments. With the increase in inland navigation activities, oil slick simulation models for rivers and lakes are needed.

Two computer models, named ROSS and LROSS, have been developed for simulating oil slick transport in rivers and lakes, respectively. The study was originated by the Detroit District, U.S. Army Corps of Engineers in relation to the Great Lakes limited navigation season extension study. The oil slick transformation processes considered in these models include advection, spreading, evaporation and dissolution. These models can be used for slicks of any shape originated from instantaneous or continuous spills in rivers and lakes with or without ice covers. Although developed for the need of the connecting channels in the upper Great Lakes, including the Detroit River, Lake St. Clair, the St. Clair River and the St. Marys River, these models are site independent and can be applied to other rivers and lakes.

The programs are written in FORTRAN programming language to be compatible with FORTRAN77 compiler. In addition, a user-friendly, menu-driven program with graphics capability was developed for the IBM-PC AT computer, so that these models can be easily used to assist the clean-up action in the connecting channels should an oil spill occur.

This report is one of four volumes, which together provide a complete description of the analytical formulation of the models, the logic and structures of the computer programs, and the instructions for using the models (Shen et al. 1990, in prep., Yapa et al. 1991).

This volume presents the computer model LROSS. The model simulates the transport of an oil slick in a lake and traces this transport process as the slick moves into and along a river. This model is an extension of the model ROSS presented by Shen et al. (in prep.).

The analytical formulation of the computer model was presented by Shen et al. (1990). Formulations of the oil slick transformation and river current distribution are the same as those developed in the model ROSS. The lake current distribution is computed using the rigid-lid lake circulation model (Schwab et al. 1981, 1984, Bennet et al. 1983). The flow chart presented in Figure 1 outlines the structure of the model. Discussions of some of the computer logic and techniques that were not discussed in the other reports will be given in the following sections. Detailed presentations of the computer model, input data files and model output are given in later chapters.

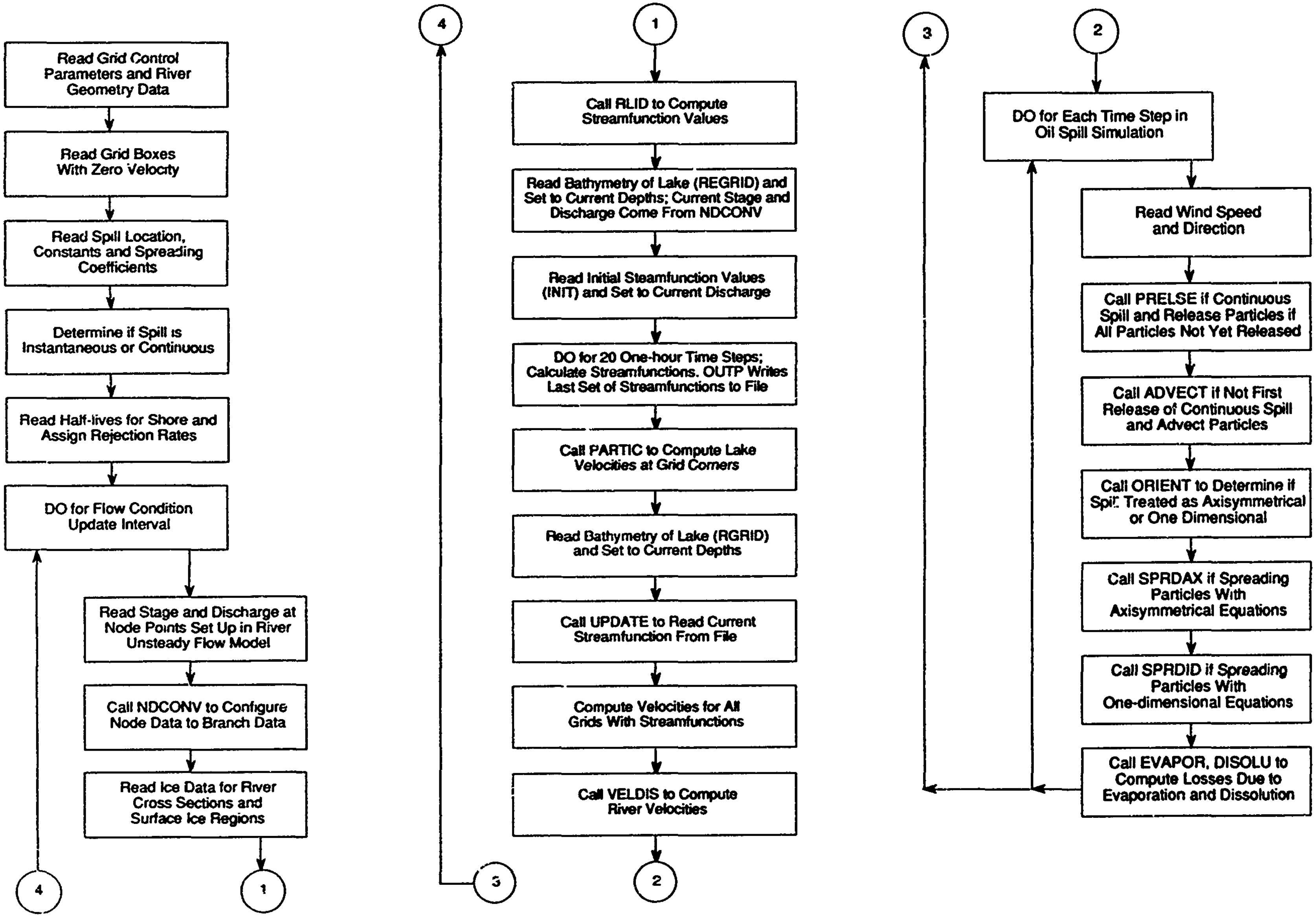


Figure 1. Flow chart of computer simulation model.

MODEL IMPLEMENTATION

Initial input

Grid control data and river geometry

The variables that govern the size and number of lake and river grids are first read into the program. Those dealing primarily with the lake are used to determine whether a point is located in either the lake or the river. This is extremely important since the correct grid size must be used when performing specific calculations. The information describing the lake and river grid schemes is presented later.

Next, the data describing the river geometry are read. This information includes:

- Branch starting and ending cross sections;
- Cross-section locations, orientation and connection sequence;
- Points describing cross-section geometry; and
- Boundary grid boxes for river and lake shorelines.

The detailed procedure for creating and organizing the river data can be found in Shen et al. (in prep.). The river is organized into a series of branches. Each branch covers a specified stretch of the river and contains a number of cross sections depending on the available field data and the accuracy requirements of this computer model.

Spill data and spill type

The information that describes the actual spill is now provided. These data control the size of the spill, the number of particles used to represent the spill, and the time scales for both the duration of oil spill simulation and the spill. Also, the coefficients and constants used in the spreading, evaporation and dissolution phases are read. All of these data are user dependent. This implies that the user has the option of locating a hypothetical or real spill anywhere in the lake or river system with the desired physical properties.

The spill simulation time step and the spill duration are used to establish the spill type. If the spill duration is greater than half of the simulation time step, the spill will be considered continuous. Otherwise, the spill will be considered to be instantaneous. Details for releasing particles as a continuous spill will be discussed shortly.

River and lake computations

Updating flow conditions

The computer model has the ability to re-compute the depth-averaged surface velocities in both the lake and the river at a specified time interval. The interval is the time step used in the river unsteady flow model. Its magnitude depends on the need for updated flow conditions over the course of the spill simulation. For example, the flow conditions may be updated every 3 hours in a total simulation of 24 hours. At the time interval, the stage and discharge conditions for all nodes in the unsteady river model (Thomas 1984) are read. Subroutine NDCONV converts this information into the stage and discharge boundary conditions for each branch of the river.

The lake circulation model requires the stage and discharge at the beginning of the first river branch (the lake–river interface) as boundary conditions for computing the correct stream function values.

Lake circulation

Subroutine RLID is next called to calculate the stream function values at the corners of the lake grids. The lake depths, initial stream function values and meteorological data (wind speed, wind direction and location of meteorological station) are required input for this routine. The depths are given for all grids comprising the lake and are read in through subroutine RGRID along with various additional parameters. Initial stream function values are read using subroutine INIT for the same grids, in addition to the grids needed to maintain the "no-flow" into the shoreline boundary condition. Finally, the wind data must be supplied at the unsteady flow model time interval.

Ice data

Data describing the location and extent of ice in both the river and the lake are read in next. In the river the cross-section ice information is used to calculate the ice cover effects when computing the streamtube velocities by increasing the hydraulic radius. In the lake the ice region data serve as an index for handling the shear stress term in the governing equations. For both the river and the lake, this information describes the regions where ice is encountered so that the proper spreading and advection equations may be applied.

Ice stress and wind stress

If an ice cover is present, there will be no wind stress. However, an additional shear stress is caused by friction on the underside of the cover. To index the presence of an ice cover, two arrays are initialized in RLID for each grid box in the lake. One array, ZWND (I,J), is set to either one or zero depending upon whether the ice cover is or is not present. The other array, FR(I,J), represents the drag coefficient in the quadratic drag law. Without an ice cover the drag coefficient equals the bed drag coefficient only. With an ice cover the ice drag coefficient is added to the bed drag coefficient.

Lake boundary and initial conditions

The stream function values and depths are initially set in the model for a reference discharge with the condition that inflow equals outflow. If the initial stage and discharge read from the river unsteady flow model is different from these reference values, the stream functions and depths must be changed to reflect the change. The depths merely require the increase or decrease in size depending on whether the new stage is higher or lower. However, even after a quick adjustment to the stream function values, the circulation model is run for a minimum of 20 one-hour time steps to obtain the quasi-steady-state stream function distribution at the initial flow condition.

These quasi-steady-state stream function values are saved for later computation of lake velocities for the initial period. The stream function output is controlled by subroutine OUTP. When the boundary conditions for the river branches are again updated by the river unsteady flow model time interval, the stream function values must be updated as well according to the new boundary condition at the lake–river interface. However, a smaller number of one-hour time steps in the update interval (3–6 hours) is needed instead of 20 hours.

Figure 2 gives a clearer interpretation of the method of 1) reading initial stream function values, 2) running

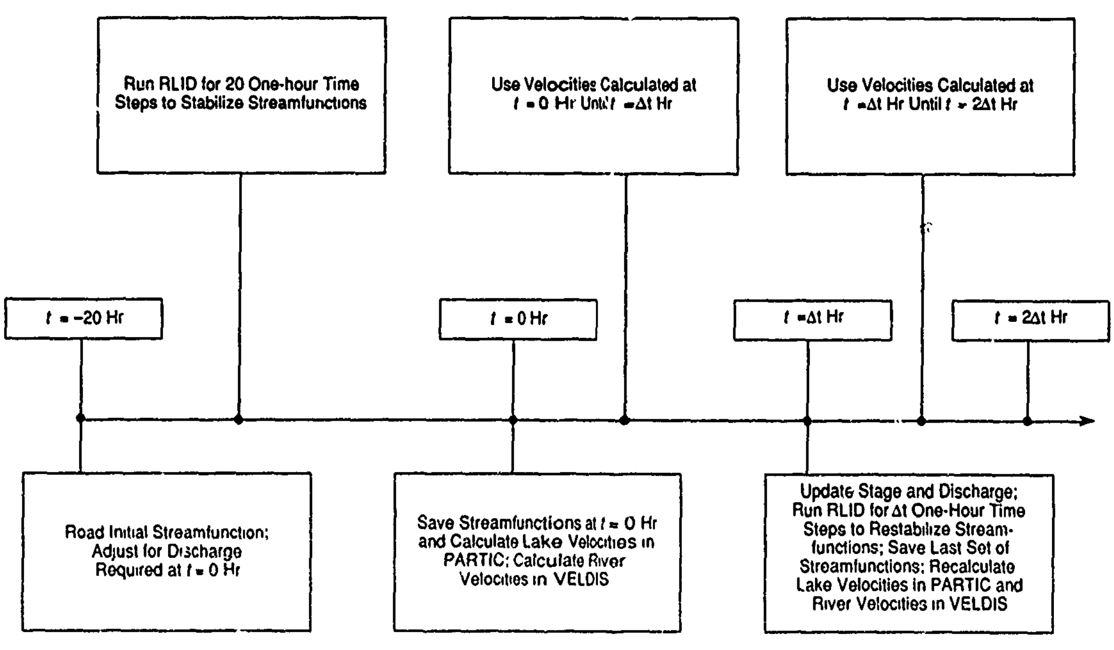


Figure 2. Time line for computing and re-computing stream function and lake velocity distributions.

the lake circulation model for 20 one-hour time steps, 3) using the last set of stream functions, calculating the lake velocities and using them from the initial spill time up to the first update of flow conditions, 4) rereading the boundary conditions at the update interval, and 5) recomputing stream functions and velocities to be used up to the next update of flow conditions.

Lake velocities

Once the stream function values are known for each grid box, the grid box velocity is computed in subroutine PARTIC. It is necessary to reread the bathymetric data to update the depth array before its use in PARTIC. Subroutine UPDATE reads the current stream function values prior to calculation of lake velocities. Depth-averaged velocities are calculated for every grid containing a stream function value. The model first computes the transports *M* and *N* between adjacent values of stream functions as shown in Figure 3. Then the velocity components are computed at the transport points and shifted back to the defined stream function point for that grid. Finally, a four-point average, taken using velocities at all corners of the grid, is assigned to the grid center.

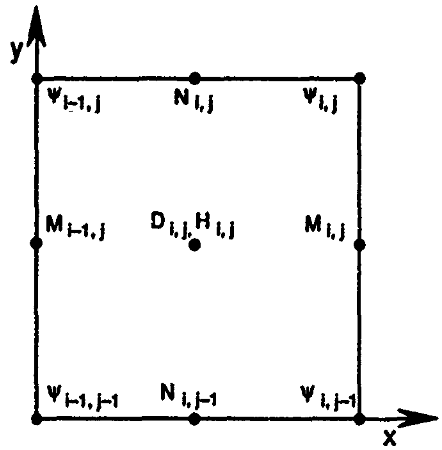


Figure 3. Positions of variables in the finite-difference grid of the lake circulation model. (After Schwab et al. 1981.)

River velocities

The depth-averaged velocities for the river are calculated in subroutine VELDIS. Using the streamtube approach, velocities are calculated and assigned coordinates corresponding to the center of each streamtube. A velocity is then assigned to the grid box in which the coordinates lie. This procedure is carried out from one branch to the next for each cross section in a branch. A predetermined number of interpolated velocities are next calculated at equidistant points between consecutive cross sections in the same streamtube. These velocities are assigned to the grid boxes in which they lie. Once the interpolations have been completed for all streamtubes between all cross sections, the river is scanned for grid boxes requiring a velocity. Starting from the beginning of the river, velocities in the adjoining grid boxes above, below and on either side of a grid without velocities are averaged and assigned to that grid.

Slick transformation

Wind component of drift velocity

The wind component of the drift velocity is considered to have the same magnitude and direction over the entire lake–river region. However, the wind data are input for every time step in the spill simulation, thus providing more flexibility in their use. By inputting the predicted or expected wind conditions along the path of the slick, the wind information is used only in the area in which it pertains, despite its overall constancy.

Continuous spills

If the spill is determined to be continuous, subroutine PRELSE is called to control the release of oil particles. The logic in PRELSE used to model a continuous spill considers the total spill to be a series of particle releases. In this way the oil can be released in the model continuously, but the volume of oil released up to a point in time can be spread as if it were an instantaneous spill. The number of releases is equal to the spill duration divided by the simulation time step. The release of particles is done uniformly in time over the spill simulation time step.

The actual sequence used is as follows. At the first time step of the oil spill simulation, a group of particles is released uniformly in time, advected (in PRELSE) and then spread according to the total volume they represent. When the subsequent calculations are completed for that time step, another group of particles is released and advected (in PRELSE) for the next time step. The particles that were released prior to this time must

be advected as well. This is done using another subroutine (ADVECT), which will eventually be the sole means of advecting the particles once the entire continuous spill has been released. Furthermore, when the spreading is computed, the entire spilled volume up to that time is used, not just the volume of the particles released last.

Advection

Open water. The source of the advective wind velocity has already been described. The appropriate water velocity to use depends on which grid a particle is currently located. All points in a grid are considered to experience the velocity assigned to that grid, so if a particle is situated anywhere inside of a grid, that grid's velocity is used when computing the overall drift velocity for the particle.

Ice-covered region. If a particle is in an ice-covered region, the first condition for advection under ice to occur is that the threshold velocity be exceeded.

Spreading in open water

Axisymmetrical spreading. If the criteria for using axisymmetrical spreading are met, subroutine SPRDAX will perform the necessary computations for this type of spreading. Use of the axisymmetrical equations is accomplished by first dividing the slick into eight segments, each encompassing $\pi/4$ radians. This allows for the probable distortion in the slick from a truly circular slick. Each pie segment will contain a number of particles depending upon the location of the particles in the slick. The particles in each segment will be spread radially according to a computed spreading rate. Since the spreading equations are based on a circular slick, the volume used to compute the spreading rate equals eight times the volume of oil in the segment. In this way the correct magnitude of the spreading rate is computed.

The spreading rates computed are considered directly applicable to particles at the mean radius of the segment. The magnitude of the spreading rate for other particles is weighted according to the ratio of the particle's position relative to the slick centroid and the distance to the mean segment radius.

One-dimensional spreading in open water. If the criteria for using one-dimensional spreading are met, subroutine SPRD1X or SPRD1Y will perform the necessary computations for this type of spreading. SPRD1X is used when the oil is spread primarily away from the y axis (in the x direction) and SPRD1Y away from the x axis (in the y direction). The technique used to model the one-dimensional case (in both SPRD1X described here and SPRD1Y in parenthesis) is similar to the axisymmetrical case except that the slick is broken up into strips instead of circular segments. Each strip is one grid box long in the y (or x) direction and as many grid boxes wide in the x (or y) direction to accommodate all the particles in the strip.

Spreading rates are computed independently on each side of the strip centroid. Since the one-dimensional equations apply to a symmetrical strip, the volume used to calculate one side's spreading rate equals twice the volume actually present in the strip. In this way the correct magnitude of the spreading rate is computed, and deviations in the slick shape from a symmetrical shape along the entire slick centroid can be accounted for. Again the spreading rate is applicable to particles at the mean strip width on one side of the slick. The spreading rate for the remainder of the particles is weighted according to the ratio of the distance of the particle from the strip centroid and the mean (upper or lower side) strip width.

Spreading under an ice cover

When an ice region is encountered, the choice of using open water spreading or spreading under an ice cover first depends on whether or not the oil is still leaking from its source. No spreading under the ice cover will occur for an instantaneous spill or once the continuous leak stops. If the leak is in progress and conforms to an axisymmetrical shape, the segments under ice will spread.

Weathering effects

Oil losses due to evaporation and dissolution are computed in subroutines EVAPOR and DISOLU, respectively. Once the evaporative loss has been computed, the representative oil volume of each particle is reduced. Oil losses due to dissolution are small compared to those from evaporation, and this loss neither significantly changes the oil volume nor significantly changes the computed spreading rates. However, the

amount of dissolved oil is calculated and accumulated for use in assessing the impact of the oil on the aquatic environment.

Shoreline conditions

During the advection and spreading phases, oil particles can be moved beyond the boundary grids describing the river and island shorelines. Therefore, after completion of either phase, a check is made to determine if a particle has been moved onto a land grid. Arrays are used to keep track of land-trapped particles so that upon entry into subroutine BOUNDR the reaction of the oil with the shoreline can be assessed.

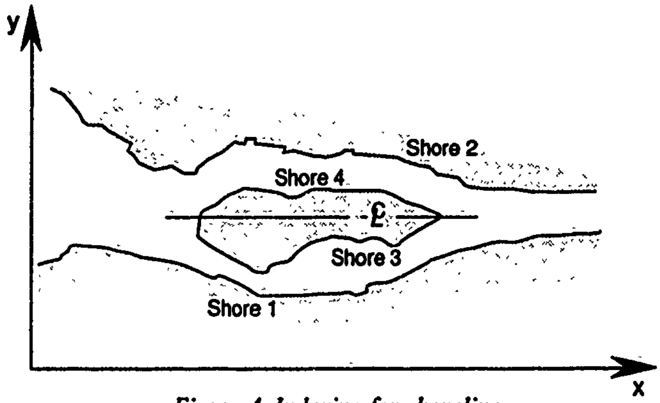


Figure 4. Indexing for shorelines.

The logic behind BOUNDR is straightforward. If a land-trapped particle is found below shore 1 or above shore 2 (Fig. 4), it is moved to the first land grid on the appropriate side of the river. If the land-trapped particle does not meet this condition, it must be on an island. In that case it will be moved to the closest island boundary grid. Once all particles are moved to the river or island boundary, the rejection rate is used to re-entrain excess particles into the river. All rejected particles are assigned to the centroid of the closest water grid.

Islands

Although not given special attention up to this point, the overall model does have the capability to deal with islands as follows:

- Island grids in the lake are treated as shallow water since RLID does not have the capability to handle the proper boundary constraints.
- The streamtube method employed in the river can handle the main channel division around one island when computing the river velocities. Additional islands, which would cause the main channel to further divide into subchannels, will be treated as shallow water and later will have their corresponding grid box velocities set to zero.
- The method used in BOUNDR to move particles into land boundary grids is limited to four shorelines. This means that when there are several islands in the same river cross section, only one island can be correctly modeled. There is no limitation if islands are in series with respect to the x axis. When assigning boundary grids, the most significant island should be selected for shores three and four.
- Using oil particles is convenient since the slick can easily divide when proceeding around an island. However, the model will only spread one slick at a time. Therefore, if the slick does separate into two patches around an island while the oil is still spreading, oil particles will be shifted to one side of the island where the appropriate spreading techniques can be used. Afterwards, the oil particles are shifted back again.

THE GRID SYSTEM

Since the model tracks the movement of oil on the water surface, it is necessary to have the capability of quickly identifying the slick position. Both river and lake water systems have their corresponding surfaces limited by finite boundaries. The computer must be able to recognize these limits for determining where to assign current velocities, where the oil will move, and when it will hit the shoreline.

A systematic technique was developed to reference any location on the two-dimensional surfaces of either the lake or the river. This technique requires that a fixed grid network be superimposed over both water bodies. The grids in the lake and the river serve both similar and dissimilar functions. The similarities are that velocities will be assigned to the grid centers for use in computing the advection of the slick and that indexing the grid

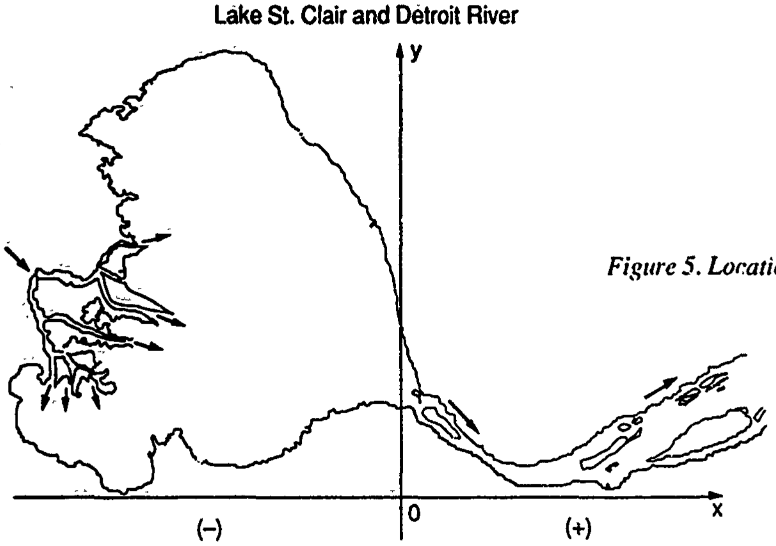


Figure 5. Location of axes in a lake–river system.

boxes controls where oil will hit the boundaries. The dissimilarity is due to separate computations and model structure of the lake circulation model when compared to the calculation of river currents.

Setting the axes

The grid network is laid out according to a cartesian system. The placement of the grids follows the x and y axis of the cartesian plane. As shown in Figure 5 for the Lake St. Clair–Detroit River system, these axes are originated from a preselected plane where the lake and river connect. The lake will be to the left of the y axis and the river will be to the right. If any shoreline is visualized as a string of x,y coordinates, the scheme used here will make all x coordinates for the lake negative and all x coordinates for the river positive. In either case the y coordinates are always kept positive since the computer logic dictates the x axis as the lower reference line. The river is used to set the orientation of the cartesian plane. The x and y axes are placed along the principal axes of the river. The x axis follows the major orientation along the length of the river. The relative position of the x axis along the y axis is established by leaving one row of grid boxes above the x axis before reaching the lake (Fig. 6).

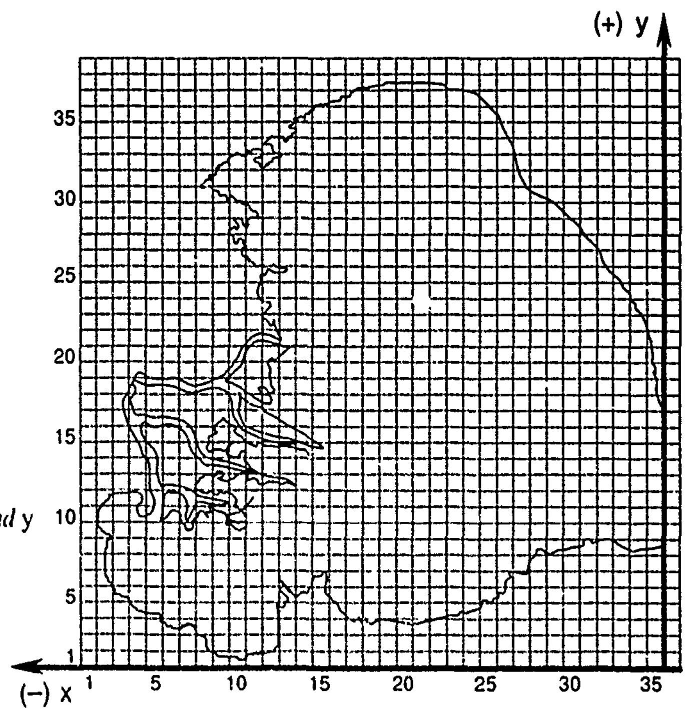


Figure 6. Lake grid boxes relative to x *and* y *axes.*

An important distinction must be emphasized between the lake and the river, since the lake circulation is computed separately from the river currents. The lake circulation model requires at least one layer of grid boxes all the way around the lake that are not in any way part of the lake shoreline. These boxes must border on the x axis at the bottom row and extend one column beyond the y axis at the far right side. The result is an overlap in river vs lake grid boxes at the lake–river interface. This will not cause any confusion in the model because the extra column of boxes past the y axis is only used for computational purposes in the lake circulation model. They will not have assigned velocities or serve as any part of the lake during the oil spill simulation.

Grid sizes

The grids must be square, and for maintaining flexibility, the size of the lake grid must be exactly divisible (to a whole number) by the size of the river grid. The implication here is that a lake grid and a river grid can be different in size as long as the lake grid is equal to or larger than the river grid. The qualification of grid sizes is needed because of the logic used for determining whether a grid is located in the lake or the river and because the lake grids are typically larger.

Grid indices

Generally both the lake and the river are described by grids in the same manner. Once the shoreline configuration for each water body is established and the grid is superimposed over them, simple counting is all that is required to identify any particular grid. Counting the x grids starts from one column to the left of the lake and continues until the end of the river is reached. All y grids are counted upwards from the x axis regardless of whether they fall in the river or the lake. The grid index figures used in the Lake St. Clair–Detroit River area are supplied in Appendix A. These figures are used when attempting to locate the site of the oil slick as well as locations of oil contaminated from the output.

Shoreline boundaries

The shorelines are schematized according to grid boxes described above. For every grid in the x direction, there are two corresponding y grids on the water side; one establishes the upper shoreline and the other establishes the lower shoreline as shown in Figure 7. Island shore grids are counted on the land side using the same method to denote upper and lower limits. All grid boxes contained between these limits, excluding those between island grids, constitute the lake or river water surface area. The data files set up for Lake St. Clair and the Detroit River are further detailed later.

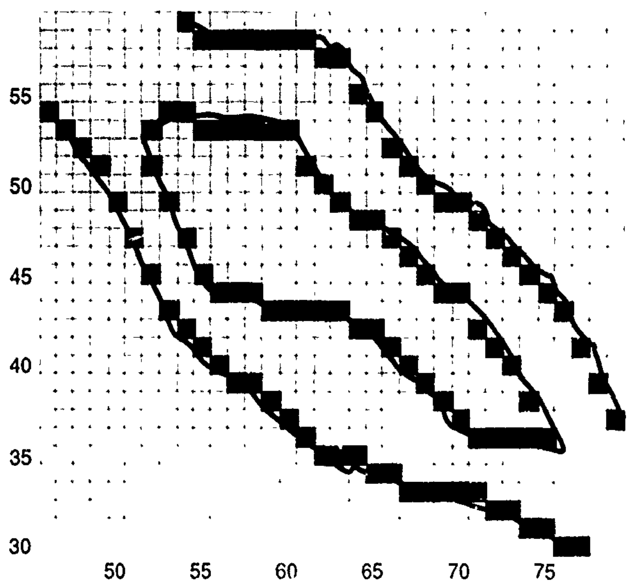


Figure 7. Portion of Figure A2 illustrating boxes selected as shoreline grid boxes.

Indexing the shorelines requires some preliminary work. Once the axes are established on appropriate charts (National Oceanic and Atmospheric Administration, National Ocean Survey, Chart 14853, 8th ed., April 14, 1979 for the Detroit River and Chart 14850, 41st ed., December 24, 1983 for Lake St. Clair), a scaled grid sheet can be placed over the charts and grids can be counted to locate the shoreline. This is sufficient for acquisition of the boundary grids, yet for graphical purposes and to facilitate interpretation of the oil spill model output, grid index figures of the type shown in Appendix A should be created. These figures are produced using software developed to record shoreline coordinates directly from the charts (Petroski and Glebas 1985). The axes must still be established on the charts, although such problems as scaling, multiple charts (Chart 14853, No. 2–14), and translation and rotation from one chart to the next can easily be handled by the computer. Furthermore, permanent indexing figures can be drawn by plotting the shoreline coordinates and the grid system together.

INPUT DATA FILES

There are three categories of input; the first is data for the computation of lake currents, the second is data for the computation of river currents and the third is miscellaneous data describing oil slick characteristics. Some of these categories overlap, as will be pointed out, although for the most part they are rather distinct. The river data are more explicitly explained in Shen et al. (in prep.), so they are only broken down into their components in conjunction with a complete sample data set in this report. The lake data will be discussed only briefly here since most details are covered in the report by Schwab and Sellars (1980). Miscellaneous data will simply be defined as the need arises. Sample data files are included in Appendix B.

A data file may or may not contain a mixture of some river, some lake and some miscellaneous data. The reason for this is to break the data up into fixed data that the user need never touch and data that must be adjusted from one spill to the next. The following is a list of the required input files with their contents.

File name	*Type*	*Unit*	*Contents*
LDETR.GEO	Fixed	1	River geometry, cross sections and branch information
LDETR.ICE	Adjust	5	Ice parameters, ice regions and lake ice thickness
LDETR.FLW	Adjust	7	Water level and discharge from unsteady
LDETR.BND	Both	8	Half-life assignments to shore grids
LDETR.SPL	Adjust	12	Oil parameters, spill location and wind component of advection
LAKEWIND.DAT	Adjust	10	Meteorological data for lake
LAKEBATH.DAT	Fixed	13	Lake bathymetry and parameters
LAKEINIT.PSI	Fixed	14	Initial stream function values in lake

The files are generally broken up into blocks and cards. A block covers a broad classification of data, which may contain one or more card types. A card type is one line of specific data that is sometimes repeated. (For example, Block 5 in LDETR.GEO has Cards 1 and 2, where Card 2 is repeated as many times as needed.) By inspecting the example of a card and comparing it to the complete sample data set at the end of this chapter, it is easy to see how the entire file comes together.

Most of the data read into the model is in list-directed I/O (free format). If column numbers are shown, the data must be formatted accordingly; otherwise it is necessary to put only one space or comma between each number in a card.

River data files

LDETR.GEO

The LDETR.GEO file contains the complete geometric description of the river. This also includes shoreline grid boxes and grid control parameters for the lake. The file consists of five blocks of information. All blocks are listed below with descriptions and corresponding components.

None of the data in this file needs to be adjusted from one spill to the next. You may choose to add additional

cross sections, change the number of branches, relocate shore grids, etc. However, consult Shen et al. (in prep.) before making the attempt.

LDETR.GEO; Block 1 (Branch and grid information)
Card 1 (Identification)
Example:
DETR Lake St. Clair and Detroit River

Variable name	*Type and length*	*Column number*	*Definition*
WORD	A4	1–4	Key word identifying river
TEXT	19A4	5–80	Any text to describe the purpose of computer run

Card 2 (Grid control parameters for lake and river)
Example:
16 35 285 4000 500 7 –1.4E+05

Variable name	*Type and length*	*Column number*	*Definition*
NBRNCH	Integer	—	Number of branches
LGRIDX	Integer	—	Number of x grids along lake
NGRIDX	Integer	—	Total number of x grid boxes
DXL	Real	—	Size of lake grid (ft)
DXR	Real	—	Size of river grid (ft)
KINTM	Integer	—	Number of velocity interpolations between cross sections in a streamtube
BEGLK	Real	—	X coordinate of lake grid origin (ft)

Card 3 (Division of cross sections into branches)
Example:
2 5 8 10 15 18 22 27 29 31 33 35 41 44 50 52

Variable name	*Type and length*	*Column number*	*Definition*
LCSTSQ(I)	Integer	—	Last cross section in each branch; last branch—use second last cross section; there must be NBRNCH numbers (one for each branch); if line is not long enough, continue on another card

LDETR.GEO; Block 2 (Cross-section location and connection information)
Card 1 (one card for each cross section)
Example:
1 (250.,30500) 1.57079630 11 11 2 0

Variable name	*Type and length*	*Column number*	*Definition*
J	Integer	—	Cross-section number (for checking)
CORDLB(I)	Complex	—	Complex variable giving x and y coordinate locating cross section on reference shore (ft, ft)
SCTANG(I)	Real	—	Angle (radians) cross section makes with positive x axis
NSTUBE(I)	Integer	—	Number of streamtubes at current cross section
NUMCON(I)	Integer	—	If all streamtubes continue to next cross section undivided = 11; if streamtubes divide into two channels from main channel = 12; if streamtubes from divided channel connect back to main channel = 21
NFIRCO(I)	Integer	—	Next cross section connecting to current cross section; for a divided channel around an island, this represents the first cross section connected to in the lower division from the main channel cross section
NSECO(I)	Integer	—	For a divided channel around an island, this represents the first section connected to in the upper division from the main channel cross section (if no island = 0,

Variable name	Type and length	Column number	Definition
			if lower division complete and returning to upper division = 888, if both divisions complete and resuming main channel = 999)

LDETR.GEO; Block 3 (Cross-section geometry)

Card 1 (one card for each cross section)

Example:

1 17 571.71

Variable name	Type and length	Column number	Definition
J	Integer	—	Cross-section number (for checking)
NSLSCT(J)	Integer	—	Number of sounding depths used to describe the cross-section geometry
ZD(J)	Real	—	Reference datum for cross-section *J* from which the sounding depth is evaluated (ft)

Card 2 [As many cards as required to input NSLSCT(J) sets of YWID,Z]

Example:

1375.0 6.0 1675.0 24.0 3000.0 21.0 3575.0 16.0 4000.0 23.0

Variable name	Type and length	Column number	Definition
YWID(I,J)	F8.2	—	Distance from the reference shore to the J^{th} sounding depth in the I^{th} cross section (ft)
Z(I,J)	F8.2	—	J^{th} sounding depth for the I^{th} section (ft)

Note: Block 3 must be repeated LCSTSQ (NBRNCH) times (i.e. = number of cross sections defined)

LDETR.GEO; Block 4 (Boundary grid boxes in lake and river)

Card 1 (one card for each grid in the x direction)

Example:

7 4 12 10 11

Variable name	Type and length	Column number	Definition
J	Integer	—	*X* grid box number
IGRILB(J)	Integer	—	*Y* direction grid box number of the lower river boundary for J^{th} x grid (water side grid box)
IGRIUB(J)	Integer	—	*Y* direction grid box number of the upper river boundary for J^{th} x grid (water side grid box)
IGRILB1(J)	Integer	—	*Y* direction grid box number of lower island boundary for J^{th} x grid (land side grid box)
IGRIUB1(J)	Integer	—	*Y* direction grid box number of upper islanf boundary for J^{th} x grid (land side grid box)

LDETR.GEO; Block 5 (Define grids having zero velocity in lake and river)

Card 1

Example:

76

Variable name	Type and length	Column number	Definition
NZRVB	Integer	—	Number of boxes to be assigned zero velocity

Card 2 (one card for NZRVB grid boxes)
Example:
9 10

Variable name	*Type and length*	*Column number*	*Definition*
IZRBX(I)	Integer	—	*X* grid number of I^{th} box to have zero velocity
IZRBY(I)	Integer	—	*Y* grid number of I^{th} box to have zero velocity

There must be NZRVB pairs of IZRBX(I) and IZRBY(I). Data may be continued to as many lines as needed.

LDETR.ICE

The LDETR.ICE file contains information identifying ice regions that the user will have to adjust as ice conditions develop. An ice region is a range of grid boxes containing ice. Ice regions in the lake must be specified first. For example, in the lake an ice region may be identified as extending from grid (15,7) to grid (18,20) (Fig. 8). The ice region then covers every grid from (15,7) to the upper shoreline of *x* column (15), all grids in *x* columns (16) and (17), and from the lower shoreline in *x* column (18) up to and including grid (18,7). An ice region may also be identified as grid (14,9) to (14,15). Then, the ice region will only extend between *y* grids (9) and (15) inclusive in *x* grid column (14). This information is used when determining if spreading and advection takes place under ice or on open water. For the lake model the ice region data locate where wind stress is zero, where the frictional stress due to the ice cover must be considered, and where the lake depths must be adjusted for the thickness of the ice.

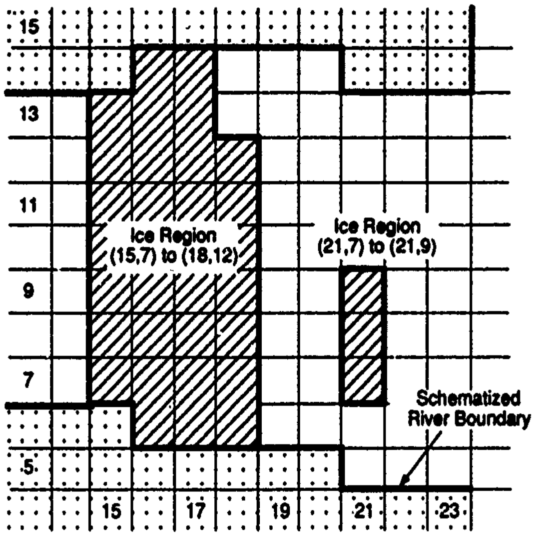


Figure 8. Defining ice regions.

LDETR.ICE; Block 1 (Ice regions in lake ar : river)
Card 1
Example:
0.035 12.5

Variable name	*Type and length*	*Column number*	*Definition*
ANICE	Real	—	Manning's n for ice roughness
AMIUO	Real	—	Viscosity of oil (lb-s/ft^2) (poise)

Card 2
Example:
1 1

Variable name	*Type and length*	*Column number*	*Definition*
NICERG	Integer	—	Total number of ice regions
LICERG	Integer	—	Number of ice regions in lake

Card 3 (1 card for all NICERG ice regions. If card is not long enough continue on next card)
Example:
15 7 18 9

Variable name	*Type and length*	*Column number*	*Definition*
NICEX1(I)	Integer	—	*X* grid at beginning of ice region
NICEY1(I)	Integer	—	*Y* grid at beginning of ice region
NICEX2(I)	Integer	—	*X* grid at end of ice region
NICEY2(I)	Integer	—	*Y* grid at end of ice region

Card 4 (one card for all LICERG ice regions)
Example:
1.0

Variable name	*Type and length*	*Column number*	*Definition*
ZLKICE(I)	Real	—	Ice thickness in lake ice region (ft). Thickness must be defined for each lake ice region (use one line, and then continue to next)

Note: Card 4 will only appear after Card 3 for lake ice regions. Ice thickness in the river is accounted for through input in the file LDETR.FLW. Cards 2, 3 and 4 must be repeated for each unsteady flow model time step.

LDETR.FLW

The LDETR.FLW file contains the water level and discharge boundary conditions for each node in the river as defined by the one-dimensional flow model (Thomas 1984). Also included are the ice conditions for each cross section in the river. These data are separate from the ice region data in LDETR.ICE. The oil spill simulation model converts this information into boundary conditions for each river branch. The lake model, RLID, uses the water level and discharge at the beginning of branch 1 (the lake–river interface) to adjust the bathymetric and stream function files to reflect the current flow conditions.

This file consists of three blocks of information. All blocks are listed below with descriptions and corresponding components. Blocks 2 and 3 must be repeated every time the velocities are updated in the model, i.e. every time step of the one-dimensional flow model. Therefore, the data in this file need to be adjusted on a more regular basis.

LDETR.FLW; Block 1 (Time step for updating flow conditions)
Card 1
Example:
3.0

Variable name	*Type and length*	*Column number*	*Definition*
UFDT	Integer	—	Time step in one-dimensional flow model (hr)

LDETR.FLW; Block 2 (Discharge and water level)
Card 1 (one card for each node in the one-dimensional model)
Example:
573.72 149190.

Variable name	*Type and length*	*Column number*	*Definition*
WL(I)	F6.2	—	Water level at I^{th} node (ft)
Q(I)	F10.0	—	Discharge at I^{th} node (cfs)

LDETR.FLW; Block 3 (Ice thickness information)

Card 1

Example:

1

Variable name	*Type and length*	*Column number*	*Definition*
ICINFO	Integer	—	Number of cross sections with ice-covered conditions; if there are no ice-covered sections, set ICINFO = 1 and then in Card 2, define an arbitrary section number to be "OPEN."

Card 2 (one for ICINFO cross sections when river contains ice)

Example:

2 OPEN

Variable name	*Type and length*	*Column number*	*Definition*
IS	I4	1–4	Cross-section number with ice-covered condition
WORD	A4	5–8	Cross-section ice cover condition: "FULL" = fully covered, "PART" = partially covered, "OPEN" = open water

Note: Each Card 2 is followed by a Card 3 and the Card 2, Card 3 combination is repeated (IS) times if WORD does not equal "OPEN." If the entire river is open water, the data file ends here.

Card 3 (For fully covered cross section only; WORD = "FULL")

Example:

1.0

Variable name	*Type and length*	*Column number*	*Definition*
FULLTI	Real	—	Ice thickness of fully covered cross section (ft); only one value read and assigned to entire cross section

Card 3 (For partially covered cross section only; WORD = "PART")

Example: If NSLSCT(IS) = 9

1.0 1.0 0.9 0.8 0.5 0.0 0.0 0.7 0.8 1.1

Variable name	*Type and length*	*Column number*	*Definition*
TICE(I,J)	Real	—	Ice thickness of partially covered cross section (ft); there must be one value for each NSLSCT(IS) sounding depth location plus one additional; measurements start on the reference shoreline and proceed from one sounding point to the next until all points have some ice thickness value

Note: The one additional thickness is required since the sounding depth on the reference shoreline is taken as zero and is not input through data, yet an ice thickness may still be required at that point.

LDETR.BND

The LDETR.BND file contains one block of data to identify the oil retention and rejection characteristics of shorelines. The user can set any shore grid box with one of the ten predetermined half-life values defined internally to the computer model. The possible values are given later. Once the half-life values are assigned, this file shouldn't require any further changes. This, however, is left up to the user's discretion.

LDETR.BND; Block 2 (Half-life data for lake and river)

Card 1 (one card for each range of grid boxes)

Example:

1 1 285 10

Variable name	*Type and length*	*Column number*	*Definition*
K	Integer	—	Shore number; see Figure 4
LFROM	Integer	—	Beginning limit (grid box number) for half-life designation to shore
LTO	Integer	—	Ending limit (grid box number) for half-life designation to shore
ICODE	Integer	—	Integer identifying which of the 10 half-life values to be assigned to a grid

Note: The last card must be a set of four zeros (0 0 0 0), which are used to identify the end of the data block.

LDETR.SPL

The LDETR.SPL file contains two blocks of information controlling the oil characteristics and the general spill simulation. From the viewpoint of modeling actual spills, most of the data in this file will change for each spill. If only oil spill scenarios are to be conducted, most of the parameters describing a particular type of oil may remain untouched, although such information as the initial spill location would have to be changed. For these reasons, guidelines are given later for choosing appropriate numbers for the variables described here.

LDETR.SPL; Block 1 (Simulation parameters and coefficients)

Card 1 (Type of oil; identification only)

Example:

Fuel oil no. 2

Variable name	*Type and length*	*Column number*	*Definition*
FUELTP	Character	1–16	Text for identifying the oil type

LDETR.SPL; Block 2 (Simulation parameters and coefficients)

Card 1 (Simulation time steps and printed output control parameters)

Example:

6.0 1 0 1 0 0 450.

Variable name	*Type and length*	*Column number*	*Definition*
TOTIME	Real	—	Total time of oil spill simulation (hr); this value must equal or exceed the time step in the unsteady flow model, i.e. in the FLW file
IEVERY	Integer	—	Frequency of obtaining output from PLOTNU and other subroutines, i.e. value of 2 gives output every other time step
IOPT1	Integer	—	Two possible values: 1 results in output of fixed data like cross-section geometry and shore conditions; 0 cancels this output
IOPT2	Integer	—	Two possible values: 1 results in output of computed velocities to be used for plotting; 0 cancels this output
IOPT3	Integer	—	Two possible values: 1 results in output of particle locations to be used in plotting; 0 cancels this output
IOPT4	Integer	—	Two possible values: 1 results in number plot of particle distribution (see PLOTNU); 0) cancels this output
SPLTIM	Real	—	Duration of oil spill (s); for a spill released over 7.5 minutes, SPLTIM = 450; a value of zero is allowed
DIFFUL	Real	—	Horizontal diffusion coefficient (ft^2/s) for lakes; if the default formulation is desired, set this value to −1.0
DIFFUR	Real	—	Horizontal diffusion coefficient (ft^2/s) for rivers; if the default formulation is desired, set this value to −1.0

Card 3 (Spill description and spreading equation coefficients)
Example:
350 10000. 900. 0.90 1.411E-5 7.55E-4 1.4 1.45 1.6 1.4 1.4 1.4

Variable name	*Type and length*	*Column number*	*Definition*
NTOTAL	Integer	—	Total number of particles defined in the system
SPVOL	Real	—	Total volume of oil spill (U.S. gal)
SPILDT	Real	—	Magnitude of time step for spill simulation (s)
SPGOIL	Real	—	Specific gravity of oil
ANIU	Real	—	Kinematic viscosity of water (ft^2/s)
SIGMA	Real	—	Surface tension of oil (lb/ft)
AK2I	Real	—	Gravity–inertia phase spreading coefficient (axisymmetrical)
AK2V	Real	—	Gravity–viscous phase spreading coefficient (axisymmetrical)
AK2T	Real	—	Surface tension–viscous phase spreading coefficient (axisymmetrical)
AKC10	Real	—	Gravity–inertia phase spreading coefficient (one-dimensional)
AKC20	Real	—	Gravity–viscous phase spreading coefficient (one-dimensional)
AKC30	Real	—	Surface tension–viscous phase spreading coefficient (one-dimensional)

Card 4 (Spill location and additional oil properties)
Example:
–5000. 35000. .7063E–02 .1873E–02 7.88 465.0

Variable name	*Type and length*	*Column number*	*Definition*
SPX	Real	—	*X* coordinate of initial spill site (ft); negative if in lake
SPY	Real	—	*Y* coordinate of initial spill site (ft)
VMUNI	Real	—	Molar volume of oil (ft^3/mol)
SOLUNI	Real	—	Solubility of fresh oil (lb/ft^3)
CEVP	Real	—	Coefficient *C* of evaporation characteristics of oil
TOEVP	Real	—	Boiling point temperature of oil (K)

Note: If API > 10, the program defines the evaporation characteristics using fitted curves; therefore, CEVP and T0 values have no influence on the program, although they are read. If API < 9, CEVP and T0 define the evaporation characteristics.

LDETR.SPL; Block 2 (Components of wind speed and environmental temperature)
Card 1 (one card for each time step in simulation)
Example:
10.0 270.0 50.0

Variable name	*Type and length*	*Column number*	*Definition*
VWMAG	Real	—	Wind speed (ft/s)
THETA	Real	—	Wind direction, clockwise angle from north degrees (ex. wind out of west = 180°)
TENVF	Real	—	Air temperature (°F)

Lake data

LAKEWIND.DAT

The file LAKEWIND.DAT contains the meteorological data for the lake circulation model. Descriptions of these data can be found in listings of subroutines RLID, PARTIC and TAU and in the report by Schwab et al. (1981). The lake model uses these data to compute the surface wind stress in both time and space. If only one wind observation is available, the time of observation must be given as 0. The most important detail to be aware of when assembling this data file is that the time interval between subsequent wind data must be the same as the time step (UFDT) for the one-dimensional river model.

This file consists of only one block of data. Since wind stations and the elevation at which data is recorded aren't likely to change, the user need merely adjust the wind magnitude and direction for each execution of the program. Of course, if the interval (UFDT) changes, so must the times for these data.

LAKEWIND.DAT; Block 1 (Lake meteorological data)
Card 1 [one card for each wind station, maximum 25 wind stations per time interval (UFDT)]
Example:
0. 42.42 82.42 30. 64. 54. 15.0 180

Variable name	Type and length	Column number	Definition
TLAST	G10.4	1–10	Time at which wind observation is made (hr from initial spill)
RLAT	G10.4	11–20	Latitude of wind observation point (degrees north)
RLON	G10.4	21–30	Longitude of wind observation point (degrees west)
Z	G10.4	31–40	Height of instruments (ft)
TA	G10.4	41–50	Temperature of air (°F)
TW	G10.4	51–60	Temperature of water (°F)
WS	G10.4	61–70	Wind speed (ft/s)
WD	G10.4	71–76	Wind direction (degrees clockwise from north)

Note: The last card must have a value for TLAST equal to −1. This denotes that no more wind information is available. All data for the same time are grouped together.

LAKEBATH.DAT

The file LAKEBATH.DAT consists of three blocks of data, which contain the bathymetric data and various grid control parameters for the lake circulation model. Description of these data can be found in listings of subroutines RLID, PARTIC and RGRID and in the report by Schwab and Sellars (1980). The lake model uses the depth when solving the vertically integrated shallow water equations written in terms of the stream function. The user need never change any data in this input file. In the event that changes are desired, consult the section later in this report or the report by Schwab and Sellars (1980).

LAKEBATH.DAT; Block 1 (Title and grid control parameters)
Card 1
Example:
LAKE ST. CLAIR BATHYMETRY

Variable name	Type and length	Column number	Definition
IPARM(5-54)	A1	1–50	Title of lake

Card 2
Example:
36 38 42. 3041534 82.9315796 4000 19 1 −2.24 39.677 10.087 −120.06

Variable name	Type and length	Column number	Definition
IPARM(1)	I5	1–5	Number of grids in x direction
IPARM(2)	I5	6–10	Number of grids in y direction
RPARM(1)	F12.7	11–22	Base latitude
RPARM(2)	F12.7	23–34	Base longitude
RPARM(3)	F5.0	35–39	Grid size (ft)
RPARM(4)	F5.0	40–44	Maximum depth(ft)
RPARM(5)	F5.0	45–49	Minimum depth (ft)
RPARM(6)	F6.2	50–55	Base rotation (counterclockwise is negative)
ZPARM(1)	F7.3	56–62	I displacement, the number of new grid squares in the x direction from the new grid origin to the old grid origin

ZPARM(2)	F7.3	63–69	*J* displacement, the number of new grid squares in the *y* direction from the new grid origin to the old grid origin
RPARM(7)	F7.2	70–76	Rotation from base (counterclockwise is negative)

Card 3

Example:

0.822690E+02 –0.418687E+01 –0.892958E+00 0.549244E+00

Variable name	*Type and length*	*Column number*	*Definition*
RPARM()	E15.6	1–60	Geographic-to-map or map-to-geographic coordinate conversion coefficients

Note: Card 3 is repeated until all 16 coefficients RPARM(8) through RPARM(23) are read.

LAKEBATH.DAT; Block 2 (Grid depths)

Card 1 (Each card contains 19 grid depths)

Example:

9 9 6 4 0 0 0 3 10 10 10 12 11 11 9 7 5 0 0

Variable name	*Type and length*	*Column number*	*Definition*
D(I,J)	F4.0	1–76	Grid depths

Note: Card 1 is repeated until all grid depths are read.

LAKEBATH.DAT; Block 3 (Time step of lake circulation model)

Card 1

Example:

1.

Variable name	*Type and length*	*Column number*	*Definition*
DT	G8.2	1–8	Time step for lake circulation model

LAKEINIT.PSI

The file LAKEINIT.PSI contains only one block of information, which consists of initial stream function values for every grid in the lake. This file requires no adjustment once it is set for a specified discharge. Details of setting up this input file and how the stream functions are used to establish boundary conditions are covered later. If no initial stream function file is available, the default will set all stream functions to zero.

LAKEINIT.PSI; Block 1 (Initial stream function values)

Card 1

Example:

0.10000E+21 0.10066E+06 0.97943E+05 0.96472E+05

Variable name	*Type and length*	*Column number*	*Definition*
S(I,J)	E12.5	1–72	Initial stream functions for lake grids

Note: The example only shows typical values. Each card in the actual file contains six stream function values.

Input adjustments

For a lake–river system (i.e. the Lake St. Clair–Detroit River area) that already has the necessary input files, very little has to be modified to run the model for a variety of spill scenarios. The cards most likely to require modification are cited below. This is followed with some guidelines and suggested values for input. No attempt is made to explain the formatting of the data changes here. Refer to earlier sections for specific formatting procedures. Cards most likely to require up-to-date information include:

Variable name	*Type and length*	*Column number*	*Definition*
LDETR.ICE	1	1	ANICE, AMIUO
LDETR.ICE	1	2	NICERG, LICERG
LDETR.ICE	1	3	NICEX1(), NICEY1(), NICEX2(), NICEY2()
LDETR.ICE	1	4	ZLKICE
LDETR.FLW	1	1	UFDT
LDETR.FLW	2	1	WL(), Q()
LDETR.FLW	3	1	ICINFO
LDETR.FLW	3	2	IS, WORD
LDETR.FLW	3	3	FULLTI or TICE(,)
LDETR.BND	1	1	ICODE
LDETR.SPL	1	1	TOTIME, SPLTIM
LDETR.SPL	1	2	NPTCL, SPVOL, SPILDT, SPGOIL, ANIU, SIGMA
LDETR.SPL	1	3	SPX, SPY, API
LDETR.SPL	2	1	VWMAG, THETA, TENVF
LAKEWIND.DAT	1	1	TLAST, TA, TW, WS, WD

Some of the variables listed here may not change at all, and other additional parameters not listed may need some revision. Whatever the case, each file specified above will be discussed in turn.

LDETR.ICE

The Manning's *n* of the undersurface of the ice cover and the viscosity of oil must be specified in this file as ANICE and AMIUO, respectively. In general, Manning's *n* can range from 0.020 to 0.065 for the underside of an ice cover. Oil viscosity is a property specific to the type of oil that has been spilled.

The user must locate ice regions in the water body and convert that information to the appropriate grids. Suggestions for handling the acquisition of these data are as follows:

1. Set up typical files for the stages of ice cover progression in both the lake and the river. In this way, seasonal data files corresponding to the state of ice conditions can be selected without spending too much time assembling data.

2. Locate ice regions on the grid maps (App. A), which have sufficient detail on the shoreline geometry and landmarks.

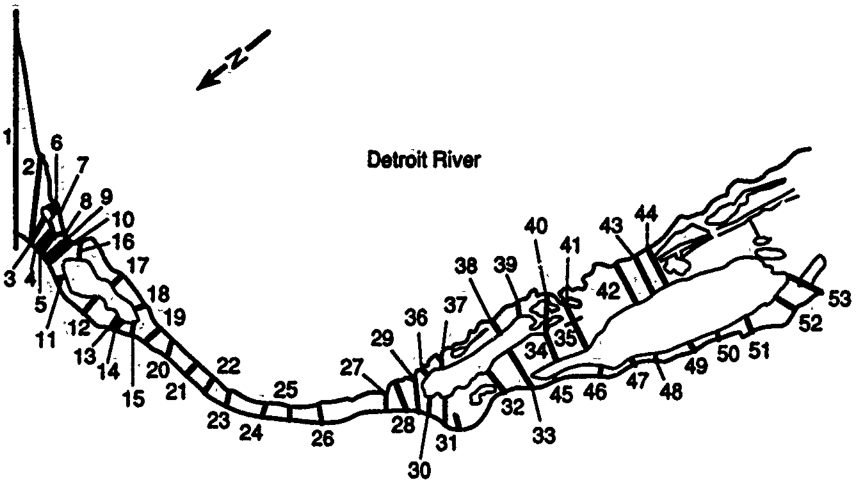
Specifying the ice region area and the number of ice regions was described earlier. Make sure to keep ice regions in the lake separate from those in the river. An ice region that extends from the lake to the river must be considered as two regions. When entering the data, specify the lake ice regions first, followed by the river ice regions. Also, note that LICERG only refers to the number of lake ice regions, whereas NICERG is the total number of ice regions. The model is only set up to handle a maximum of 20 ice regions. If more are desired, the size of arrays ZLKICE(), NICEX1(), NICEY1(), NICEX2() and NICEY2() must be increased.

The reason for specifying lake ice regions first is tied to the ice thickness data. Whenever an ice region is specified for the lake, the next information read is the corresponding lake ice thickness. The thickness ZLKICE is considered to be uniform for the entire region and is used to adjust the lake depths for the presence of ice.

LDETR.FLW

Stages Q() and discharges WL() at nodes in the river are unlikely to remain constant over time. Therefore, this information must be entered to reflect the correct flow conditions. The one-dimensional river unsteady flow model is used to obtain this information. To set up the file LDETR.FLW, simply enter the unsteady flow model time step UFDT and then the discharge Q() and water level WL(), which appear in the one-dimensional model's output. The oil spill model will handle the conversion from the nodal points in the one-dimensional model to the required branch points. Just be sure to enter the information in the same order as it appears in the unsteady flow model output.

To account for ice conditions when computing the river velocities, additional data locating ice in each cross section are required in file LDETR.FLW. Specifying this ice information for partially ice-covered river cross



Sec no.	Station	Year	Sec no.	Station	Year	Sec no.	Station	Year
1	*	1979	19	1354+02	1981	36	893+25	1980
2	*	1979	20	1326+11	1980	37	853+93	1981
3	1611+77	1980	21	1268+49	1981	38	767+74	1981
4	1573+89	1981	22	1217+22	1980	39	715+05	1980
5	1570+05	1980	23	1170+21	1981	40	*	1979
6	1589+04	1981	24	1104+70	1981	41	*	1979
7	1584+41	1981	25	1056+00	1981	42	548+10	1980
8	1570+05	1980	26	1015+81	1980	43	504+17	1981
9	1550+15	1980	27	965+47	1981	44	*	1979
10	*	1979	28	930+25	1980	45	693+07	1980
11	1518+84		29	*	1979	46	635+94	1981
12	1455+33	1981	30	893+23	1980	47	583+47	1980
13	1410+05	1980	31	785+31	1981	48	537+94	1981
14	1404+70	1980	32	785+31	1981	49	478+93	1980
15	1385+12	1981	33	732+34	1981	50	427+63	1981
16	1520+66	1980		728+51	1981	51	374+08	1980
17	1451+85	1981	34	700+00	1980	52	302+46	1980
18	1387+02	1980	35	650+68	1981	53	*	1979

* Cross sections measured from National Oceanic and Atmospheric Administration, National Ocean Survey, Chart 14853 of Detroit River, 8th Ed., April 14, 1979.

Figure 9. Cross section locations in the Detroit River.

sections needs some clarification. Remember that each cross section is described by sounding depths and distances from a reference shore at which those sounding depths were taken. The data are assembled in Block 3, Cards 1 and 2 of file LDETR.GEO, with the reference shoreline for the Detroit River as the lower shoreline in the x-y grid system. The number of sounding depths and the locations from the reference shore are not the same for each cross section. Therefore, Block 3 in LDETR.GEO must be relied on when figuring which sounding depth locations have some ice cover thickness. Figure 9 shows the Detroit River with the designated reference shoreline and cross section locations. Cross section numbers are the same as those found in LDETR.GEO. By using the given LDETR.GEO data file at the end of this section, Figure 9, and the extent of ice cover at the cross sections, you should be able to correctly input the ice thickness data for the array TICE(,).

LDETR.BND

The half-life code ICODE must be assigned to the shoreline grids along the lake and river to enable the computation of rejection or retention of oil. Ten possible half-life codes are currently available. They should be broad enough to cover any situation and are given according to the type of shoreline as:

ICODE	Half-life (hr)	Shore characteristics
1	0.033	Sheet piling
2	0.5	Commercial docks
3	1	Private docks
4	6	—
5	12	Embankments
6	18	—
7	24	Sand/gravel beach
8	48	Marsh
9	48	Shallow water

No information is available to more accurately correlate the half-life values with the shoreline characteristics other than what is given here. Torgrimson's (1984) suggested half-life values were used to arrive at those given above. The logic used to obtain these values is that the smaller the half-life, the less likely the oil will remain on the shore.

LDETR.SPL

The oil spill parameters in LDETR.SPL will require the most modification of any file from spill to spill. Any particular spill will have its own total simulation time TOTIME, simulation time step SPILDT, duration of spill SPLTIM, spill volume SPVOL, number of particles NPTCL (maximum 1000), spill location SPX and SPY, wind speed components VWX and VWY, air temperature TENVF and oil and water properties, so it will be necessary to adjust these data each time a new spill is simulated. Most of these are self-explanatory and have already been described. Those that require particular attention are the spill location, wind components and oil and water properties.

The spill location can be determined using Figure A1. Knowing the grid sizes of both the lake (currently 4000 ft) and river (currently 500 ft) and the locations of the x and y axes, a particular location can be pinpointed anywhere. Note that the lake domain has negative x coordinates and the river domain has positive x coordinates.

The wind speed and direction that are used to compute the wind component of the drift velocity must be input for every SPILDT time interval. The unit of wind speed is ft/s. The wind direction is the clockwise angle measured from magnetic north. For example, wind blowing out of the west has a direction of 270°.

For the type of oil being used in the simulation, the specific gravity SPGOIL, API index, gravity API, molar volume VMUNI and solubility in water SOLUNI must be specified. Also, the oil–water interfacial tension SIGMA and the viscosity of water ANIU are required input.

For determining evaporation rates of oil coefficient C, CEVP and boiling point temperature TOEVP are needed. The user has an option here. If the API value is greater than 9, the model automatically computes CEVP and TOEVP using the curves described earlier. The curves used are for crude oils with API values ranging from 10 to 45. The data for CEVP and TOEVP must be present in the data file, although they serve no purpose in this case. The other option is to select an API value of less than 9. In this case, values of CEVP and TOEVP will be used for computing evaporation rates. It should be noted that an oil having an API value between 10 and 45 is not necessarily a crude oil. For non-crude oils, CEVP and TOEVP should be given as input data with an APR of less than 9.

LAKEWIND.DAT

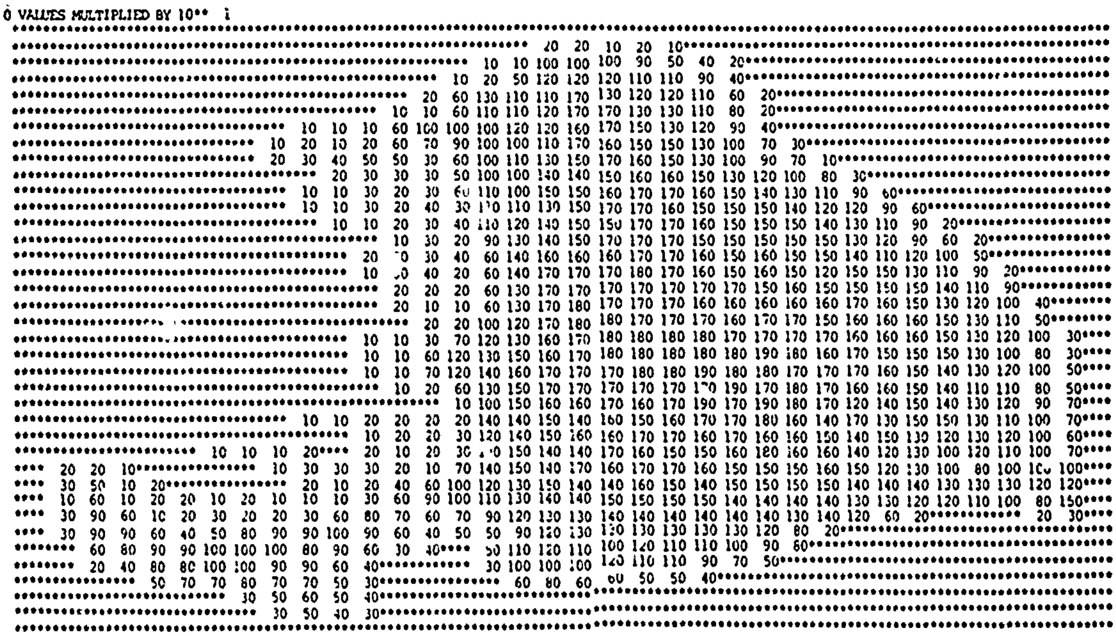
The wind data required by the lake model may come from the same wind stations where the wind speed and direction were given as input to the oil spill model. However, to protect the integrity of both the lake and the river models, the information must be read from two separate files. In the file LAKEWIND.DAT the lake model computes the proper direction for the wind speed, which is read relative to the new axial system. Therefore, the forecasted wind speed WS, wind direction (degrees clockwise from north) WD, and air and water temperatures can be placed directly in the file without any conversion or rotation. The time interval for data specification is independent of any other time step in the model. The user may simply input one line of wind data at $T = 0$ hours and the model will use these wind data for the entire simulation. The lake model will always use the last data read in if the simulation continues longer than the last time specified in LAKEWIND.DAT.

STREAM FUNCTION AND BATHYMETRY OF LAKES

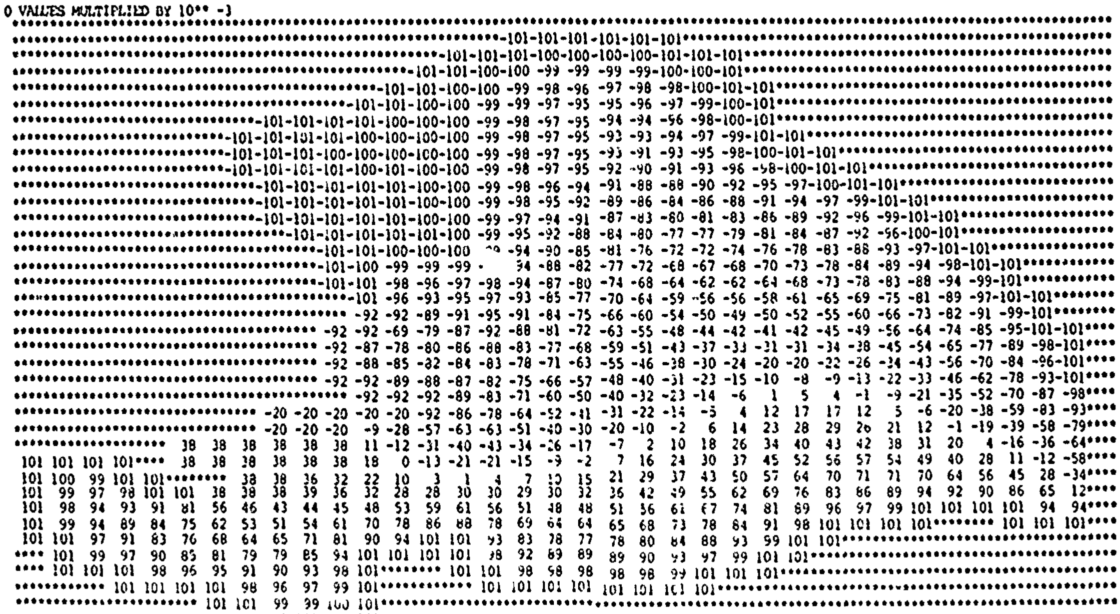
The input files LAKEBATH.DAT and LAKEINIT.PSI for Lake St. Clair can be revised if a smaller grid size or new boundary conditions are desired. The work is rather tedious and requires attention to details covered in this chapter, but it can be done. The report by Schwab and Sellars (1981) was used to direct the collection of the current Lake St. Clair files and may be consulted.

Figure 10 illustrates what the depth and stream function files look like when printed out as two-dimensional arrays. Areas in the lake that represent land are masked with a special value (SPVAL). This causes the stars (*) to be printed. The stars in the depth array (Fig. 10a) represent a depth of zero feet. The stars in the stream function array (Fig. 10b) represent a very large number (1.0E+21 is currently used). The SPVAL for the lake is used as an indicator for locating a boundary and is not part of the actual calculation of stream functions.

Close examination of the positions occupied by depths and stream functions quickly reveals that not every array location that contains a stream function value has a depth. The reason is partly because the stream functions not only serve to give the discharge between grid points, but they are also used to establish both the no-flux boundary condition at the lake shore and the discharge conditions at river mouths. Furthermore, the additional boxes with assigned stream functions are required by the second order differencing technique used to solve the



a. Depth array.



b. Initial stream function array.

Figure 10. Input files for Lake St. Clair.

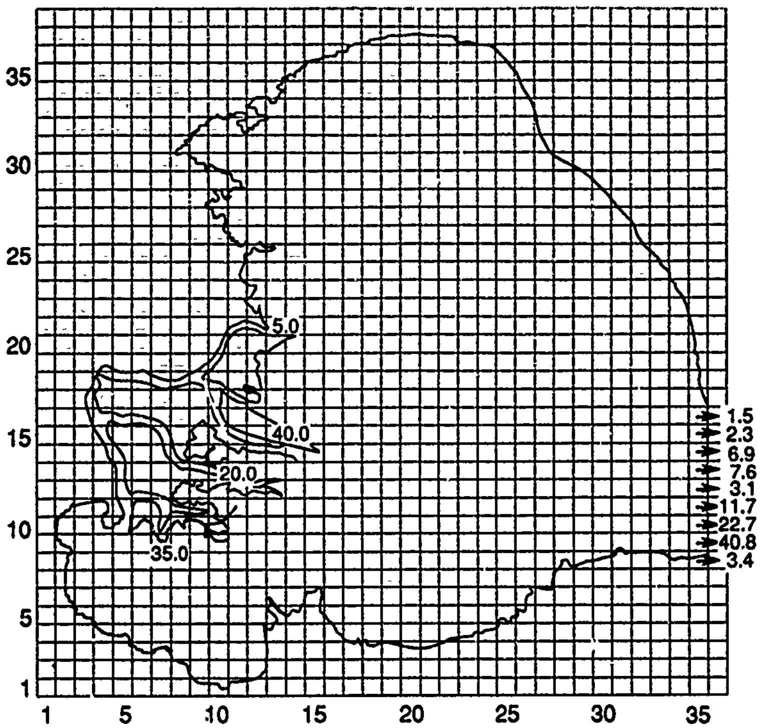


Figure 11. Discharge points, percentages of total discharge at the points, and discharge directions used in the current LAKEINIT.PSI file.

stream function equation. The no-flux condition along the lake boundary is accomplished by setting stream function values in adjacent grids equal. The difference in stream function values across the river mouth corresponds to the river discharge into or out of the lake. Figure 11 shows the discharge points, percentages and directions used in the current Lake St. Clair stream function file. Relating Figure 11 to Figure 10b shows that all numbers bordering the stars across the bottom and top of the lake are constant, and numbers bordering the stars on the left and right sides change as discharge points are encountered.

Lake bathymetry data

This section will focus on the procedure for setting up a new depth array for Lake St. Clair. First, it is necessary to draw a new grid over the lake chart (National Ocean Survey Chart 14850) with the new grid size. To avoid changing any more more parameters than absolutely necessary, grid (1,1) should originate from the same point as grid (1,1) does in Figure 4, and the current grid size (4000 ft) must be divisible to a whole number by the new grid size. Then, the geographic-to-map and map-to-geographic conversion coefficients will not be affected. These coefficients should never be changed unless a new base origin is used and the coefficients recalculated. The current model uses the original base computed by Schwab and Sellars (1981).

Second, parameters IPARM(1) and IPARM(2) are computed by counting the number of grids from grid (1,1) to the lake–river interface plus one and the number of grids from the x axis to at least one grid past the upper shoreline. Parameter RPARM(3) is changed to the new grid size. Then ZPARM(1) and ZPARM(2) are multiplied by the ratio of the old grid size to the new grid size.

Third, the grids that fall within the lake shore will be assigned an average of the sounding depths shown on the chart. Islands are currently assigned the minimum depth of the lake since the model does not take into account the proper boundary conditions around them. If the minimum or maximum lake depths change, RPARM(4) (and the island depths) and RPARM(5) must reflect these changes. At this point the new LAKEBATH.DAT file can be assembled. Note that lake depths are read from the file starting with the bottom row (left to right) in the lake and going up, so they must be set up in that order within the file.

Finally, the shore limits, IGRIUB(), IGRILB(), IGRUB1() and IGRLB1(), must be established based upon

the grids having assigned depths. This means that the new shore limits, LGRIDX, NGRIDX and DXL, must be changed in LDETR.GEO.

Stream function file (LAKEINIT.PSI)

Now that the grids containing the depths are known, the stream functions can be assigned. If the grid size was not changed, the procedure given here could be used to set up new boundary conditions in the lake.

The first step is to select the total discharge at which the file will be set (Fig. 10b was set for 201,323 cfs: the numbers shown are rounded off) and locate the grids containing the discharge points. Then every grid on the boundary of the lake containing a depth other than zero will be assigned a stream function value. The easiest way to choose the starting number and location is to take half the total discharge magnitude (100661.5 cfs in Fig. 10b), give it a positive sign, and assign that number at the lower side of the mouth of the Detroit River. Then subtract discharges from this number for the subsequent discharge points above when going from one grid to the next and assign the result to the corresponding grid. When the top of the mouth of the Detroit River is reached, the stream function value should be the same magnitude as at the lower side of the mouth but negative in sign (–100,661.5 cfs in Fig. 10b). Counterclockwise around the lake the stream function will stay constant until the next discharge point is encountered and the appropriate value recorded for that grid. Finally all grids within the lake are assigned interpolated values between the boundaries.

According to the definition of a grid i,j as shown in Figure 3, it is now possible to complete the assignment of stream functions to the additional grids mentioned earlier. Every grid i,j in the lake must have a stream function at every corner to apply the second-order differencing technique. The only way for all four corners to have stream function values is for adjacent grid boxes to have stream functions. By starting at any boundary grid and proceeding around the lake, each grid with an assigned depth is checked to see if all four corners will have assigned stream functions. If not, the additional boxes required to fill the need are assigned a stream function (of the same numerical value as the box that was checked). Upon completion of this step, all grids that require a stream function value should have one except the land grids. These are assigned the number SPVAL.

The LAKEINIT.PSI file can now be set up. Again, the numbers are read in starting from the bottom row (left to right) in the lake array and proceeding up to the highest row. Extreme caution is advised when typing numbers since an error could cause instability in the computations.

Calculating stream function values

Simple hand calculations do not give accurate interior stream function values. A program was set up to accurately determine the stream functions at the desired total discharge (written in FORTRAN 77 with adaptation to a FORTG1 compiler if file OPEN statements are modified). This program computes the steady-state stream function values for the given total discharge and boundary condition using the unsteady finite-difference scheme. The input files required to run the program are LAKEBATH.DAT, LAKEINIT.PSI and LAKEWIND.DAT. LAKEINIT.PSI is the file just created. LAKEWIND.DAT is the meteorological data file with all wind speeds set to zero. LAKEBATH.DAT is the same as that detailed earlier and described (if revised for new grid sizes) in this chapter with the addition of five more variables added to Card 3 after the time step Δt. A typical LAKEBATH.DAT and LAKEWIND.DAT file is shown in Figure 12. These are:

Variable name	*Type and length*	*Column number*	*Definition*
TT	G8.2	9–16	Total time to run program (suggest using 1500 hours)
RWD	G8.2	17–24	Reference water level for depths; 571.71 if depths taken off of Chart 14850
CLWL	G8.2	25–32	Current lake water level corresponding to current discharge TLKQ
TLKQ	G8.0	33–40	Total lake discharge at CLWL
RLKQ	G8.0	41–48	Reference discharge which was used when setting up the boundary stream function values

Note: TLKQ will become RLKQ at the end of program execution. This value and RWD must be inserted into subroutines RLID and PARTIC (DATA statement for RLKQ and RWD) prior to using the new files in the oil spill simulation. The output from the program will be a stabilized stream function array stored in a file named STREAM.DAT. This is the file that will be used as input to the oil spill simulation model but under the file name LAKEINIT.PSI.

```
LAKE ST. CLAIR BATHYMETRY
  36   38  42.3041534  82.9315796 4000    19     1 -2.24 39.677 10.087-120.06
  0.822690E+02   -0.418687E+01   -0.892958E+00    0.549244E+00
  0.284351E+01    0.110232E+03    0.182918E+00    0.235336E+00
  0.121387E-01    0.462637E-03    0.110856E-05   -0.102938E-05
 -0.313049E-03    0.905963E-02   -0.238882E-06   -0.279918E-06
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    3    5    4    3    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    3    5    6    5    4    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    5    7
   7    8    7    7    5    3    0    0    0    0    6    8    6    6    5    5    4    0    0
   0    0    0    0    0    0    0    0    0    0    0    0    0    2    4    8    8   10   10
   9    9    6    4    0    0    0    3   10   10   10   12   11   11    9    7    5    0    0
   0    0    0    0    0    0    0    0    0    0    0    6    8    9    9   10   10   10    8
   9    6    3    4    0    5   11   12   11   10   12   11   11   10    9    8    0    0    0
   0    0    0    0    0    0    0    0    3    9    9    6    4    5    8    9    9   10    9
   6    4    5    5    9   12   13   13   13   13   13   13   12    8    2    0    0    0    0
   0    0    0    0    0    0    3    9    6    1    2    3    2    2    3    6    8    7    6
   7    9   12   13   13   14   14   14   14   14   14   13   14   12    6    2    0    0    0
   2    3    0    0    1    6    1    2    2    1    2    1    1    1    3    6    9   10   11
  13   14   14   15   15   15   15   14   14   14   14   13   13   12   12   11   10    8   15
   0    0    3    5    1    2    0    0    0    0    2    1    2    4    6   10   12   13   15
  14   14   16   15   14   15   15   15   15   14   14   14   13   13   13   12   12    0    0
   2    2    1    0    0    0    0    1    3    3    3    2    1    7   14   15   14   17   16
  17   17   16   15   15   15   16   15   12   13   10    8   10   10   10    0    0    0    0
   0    0    0    1    1    1    2    0    2    1    2    3   13   15   14   14   17   16   15
  15   16   18   16   16   14   12   13   10   12   11   10    7    0    0    0    0    0    0
   0    0    0    0    0    0    1    2    2    3   12   14   15   16   16   17   17   16   17
  16   16   15   14   15   13   12   13   12   10    6    0    0    0    0    0    0    0    0
   0    0    1    1    2    2    2    2   14   14   15   14   16   15   16   17   17   18   16
  14   17   13   15   15   13   11   10    7    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    1   10   15   16   16   17   16   17   19   17   19   18   17   12
  14   15   14   13   12    9    7    0    0    0    0    0    0    0    0    0    0    0    0
   0    1    2    6   13   15   17   17   17   17   17   17   19   17   18   17   16   16   15
  14   11   11    8    5    0    0    0    0    0    0    0    0    0    0    0    0    1    1
   7   12   14   16   17   17   17   18   18   19   18   18   17   17   17   16   15   14   13
  12   10    5    0    0    0    0    0    0    0    0    0    0    0    0    1    1    6   12
  13   15   16   17   18   18   18   18   18   19   18   16   17   15   15   15   13   10    8
   3    0    0    0    0    0    0    0    0    0    0    0    0    1    1    3    7   12   13
  16   17   18   18   18   18   17   17   17   17   16   16   16   15   13   12   10    3    0
   0    0    0    0    0    0    0    0    0    0    0    0    0    2    2   10   12   17   18
  18   17   17   17   16   17   17   15   16   16   16   15   13   11    5    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    2    1    1    6   13   17   18   17   17
  17   16   16   16   16   16   17   16   15   13   12   10    4    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    2    2    2    6   13   17   17   17   17   17   17
  17   15   16   15   15   15   15   14   11    9    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    1    3    4    2    6   14   17   17   17   18   17   16   15   16
  15   12   15   15   13   11    9    2    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    2    3    3    4    6   14   16   16   16   17   17   16   15   16   15   15
  14   11   12   10    5    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    1    3    2    9   13   14   15   17   17   17   15   15   15   15   15   13   12
   9    6    2    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    1
   2    3    4   11   12   14   15   15   17   17   16   15   15   15   14   13   11    9    2
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    1    3    2    4
   3   11   11   13   15   17   17   16   15   15   15   14   12   12    9    6    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0    1    1    3    2    3    6   11
  10   15   15   16   17   17   16   15   14   13   11    9    6    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    2    3    3    3    5   10   10   14
  14   15   16   16   15   13   12   10    8    3    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    2    3    4    5    5    3    6   10   11   13   15   17
  16   15   13   10    9    7    1    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    1    2    1    2    6    7    9   10   10   11   17   16   15   15
  13   10    7    3    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    1    1    1    6   10   10   10   12   12   16   17   15   13   12    9
   4    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    1    1    6   11   11   12   17   17   13   13   11    8    2    0
   0    0    0    0    0    0    '    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    2    6   13   11   11   17   13   12   12   11    6    2    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    1    2    5   12   12   12   11   11    9    4    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    1    1   10   10   10    9    5    4    2    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    2    2    1    2    1    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
        1.       50.   571.71   574.00 190000. 201323.
```

```
        0.        42.5        82.75        30.        64.        54.        00.        270.
       -1.
```

Figure 12. Typical LAKEBATH DAT and LAKEWIND.DAT files for creating an initial stream function file.

MODEL OUTPUT

The amount of output generated is governed by several parameters and subroutines. The option number assigned to the parameter determines whether or not a specific portion of output will be generated. The following table summarizes these parameters and their functions:

Parameter	*Yes*	*No*	*Function*
IOPT1	1	0	Call subroutine PRINT to write fixed geometry of river to file OILOUT
IOPT2	1	0	Write location and magnitude of streamtube velocities to file D.VELSTR and depth-averaged grid velocities to D.VELCAR
IOPT3	1	0	Write locations of oil particles to D.OILSP
IOPT4	1	0	Call subroutine PLOTNU to write number plot of particle locations
INDPRN	1	0	Call subroutine PGPARM to write lake model input data and subroutine PRNT to write lake depths, lake stream functions and lake ice region locations

Appendix C contains selected output and graphics for two sample runs of LROSS.

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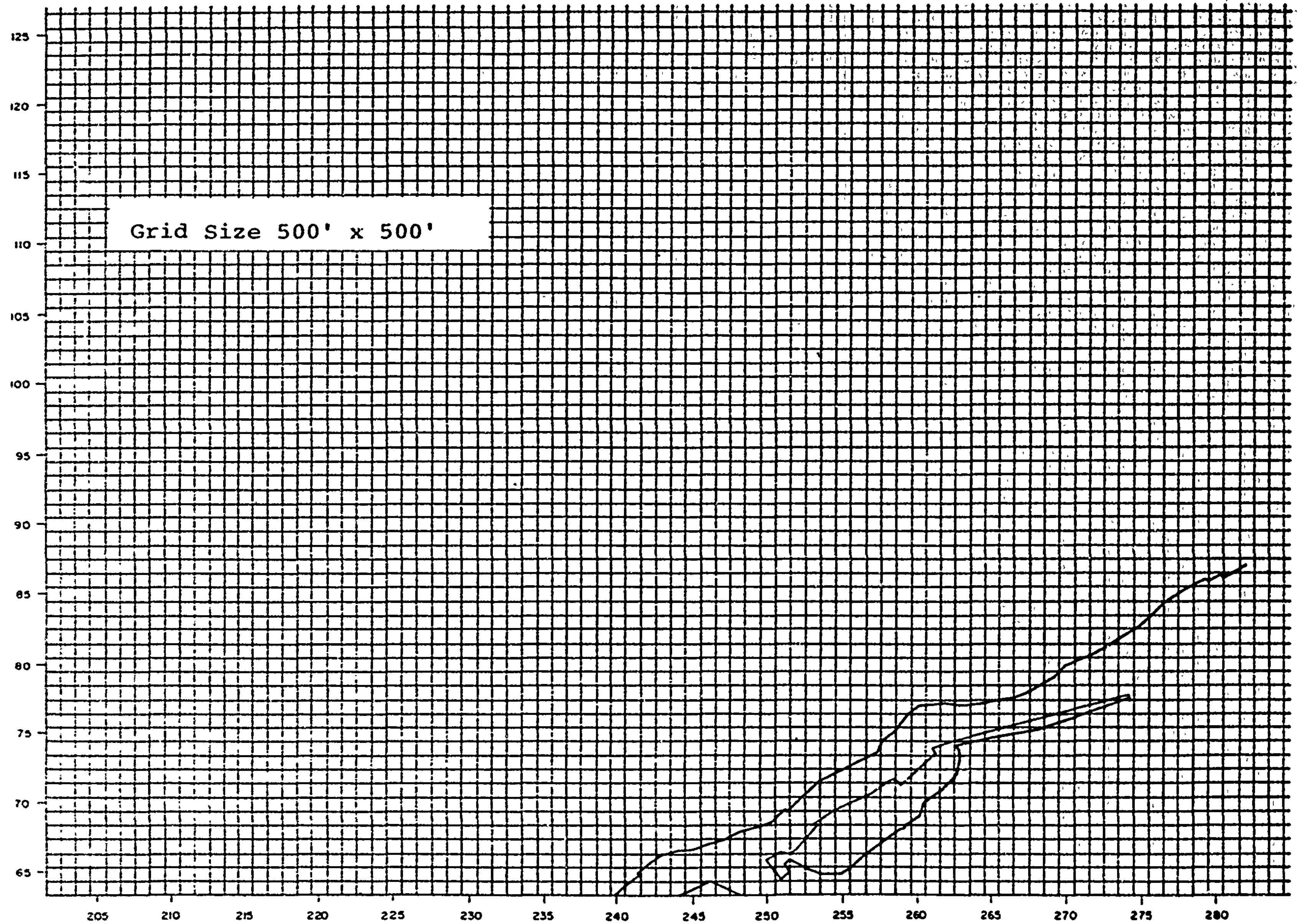


d. x grid range 202–285, y grid range 64–126.

Figure A2 (cont'd).

APPENDIX A. GRID INDEXES FOR LAKE ST. CLAIR AND THE DETROIT RIVER

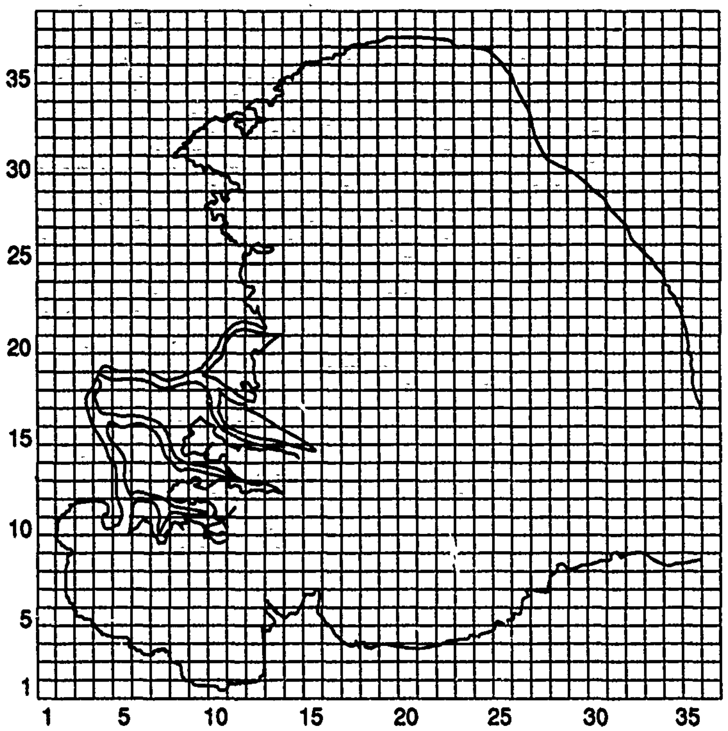
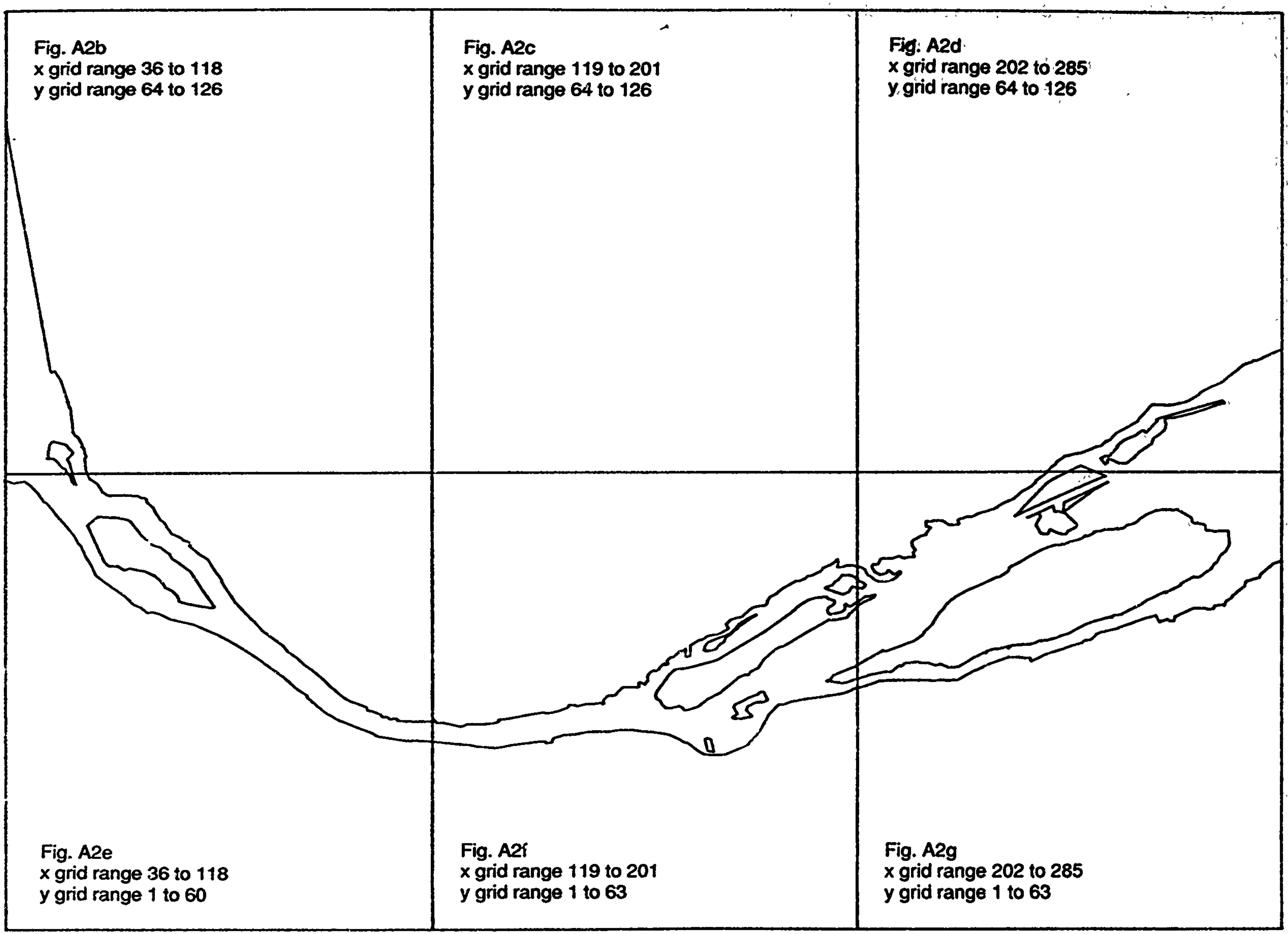
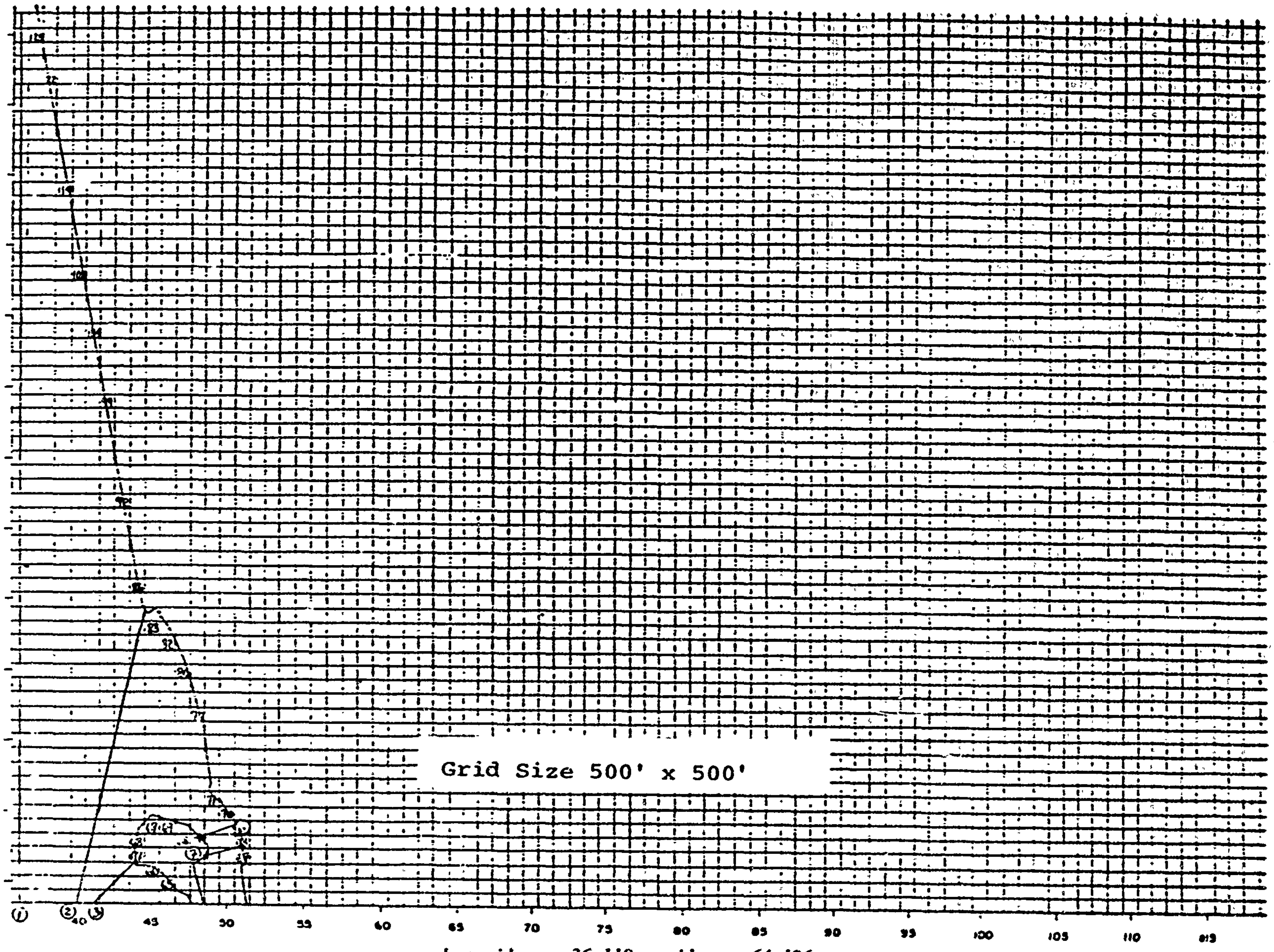


Figure A1. Grid index for Lake St. Clair (x grid range 1–35, y grid range 1–38).



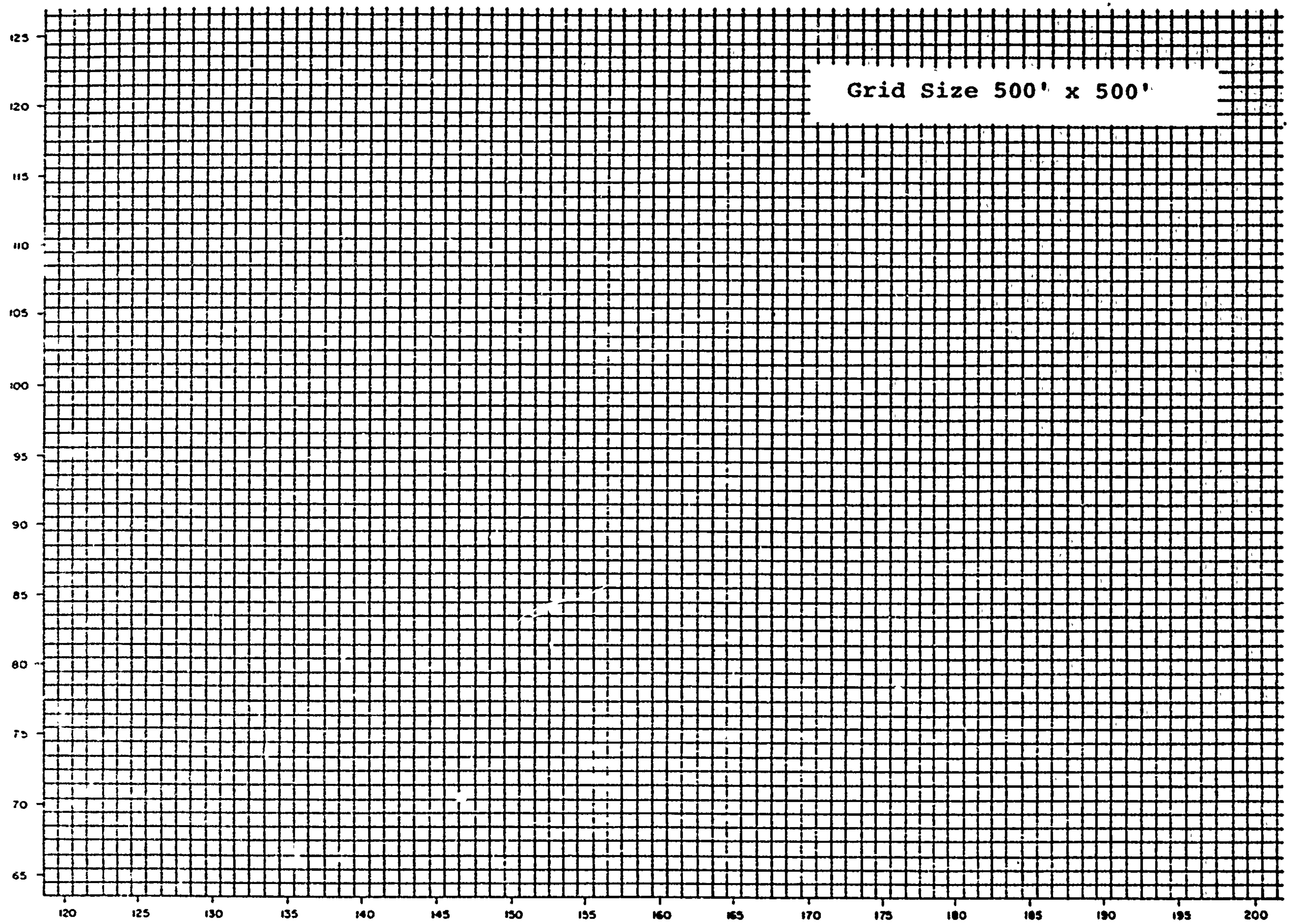
a. Index map.

Figure A2. Grid index for the Detroit River.

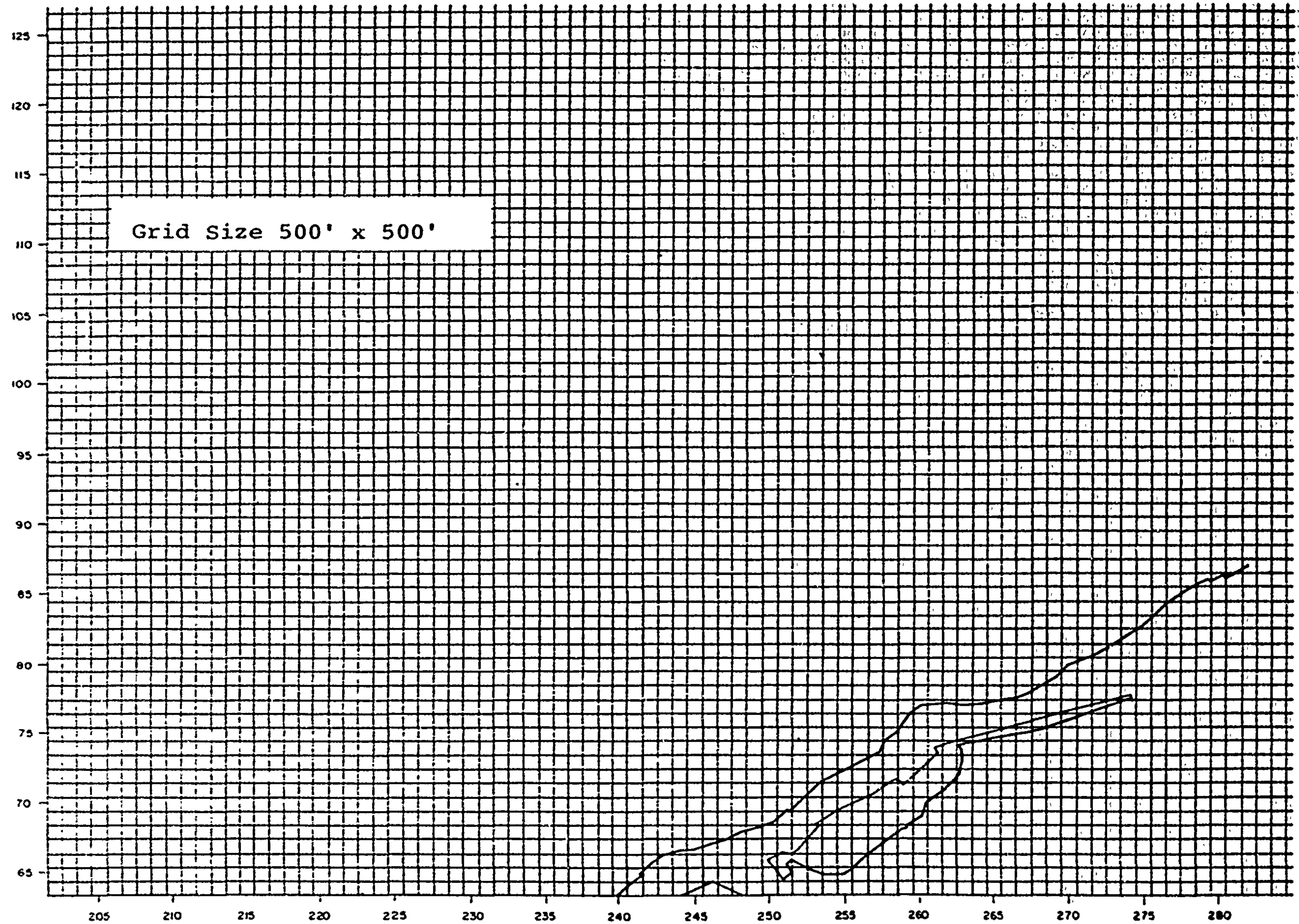


5. x grid range 36–118, y grid range 64–126.

Figure A2 (cont'd).

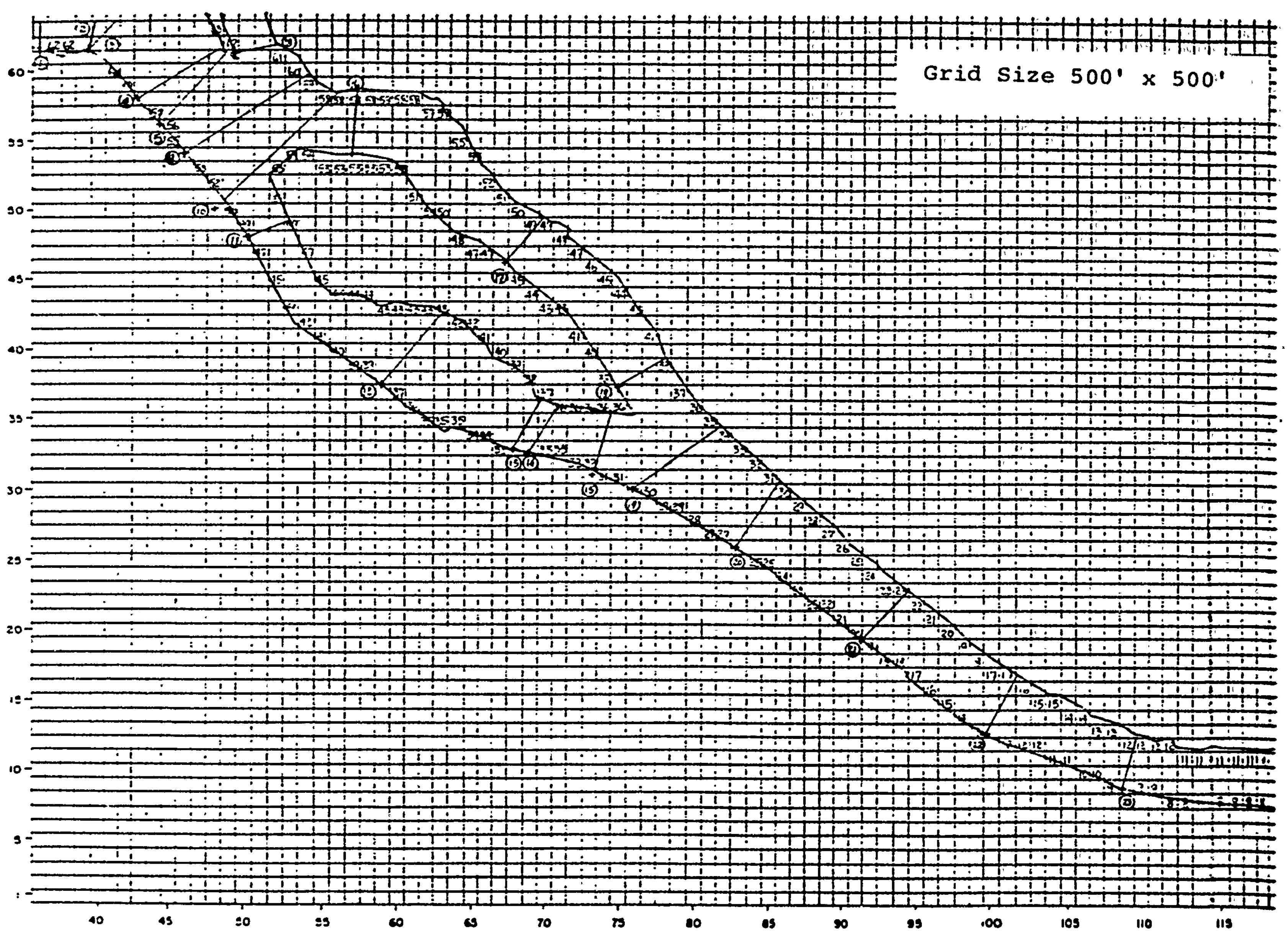


c. x grid range 119–201, y grid range 64–126.
Figure A2 (cont'd). Grid index for the Detroit River.



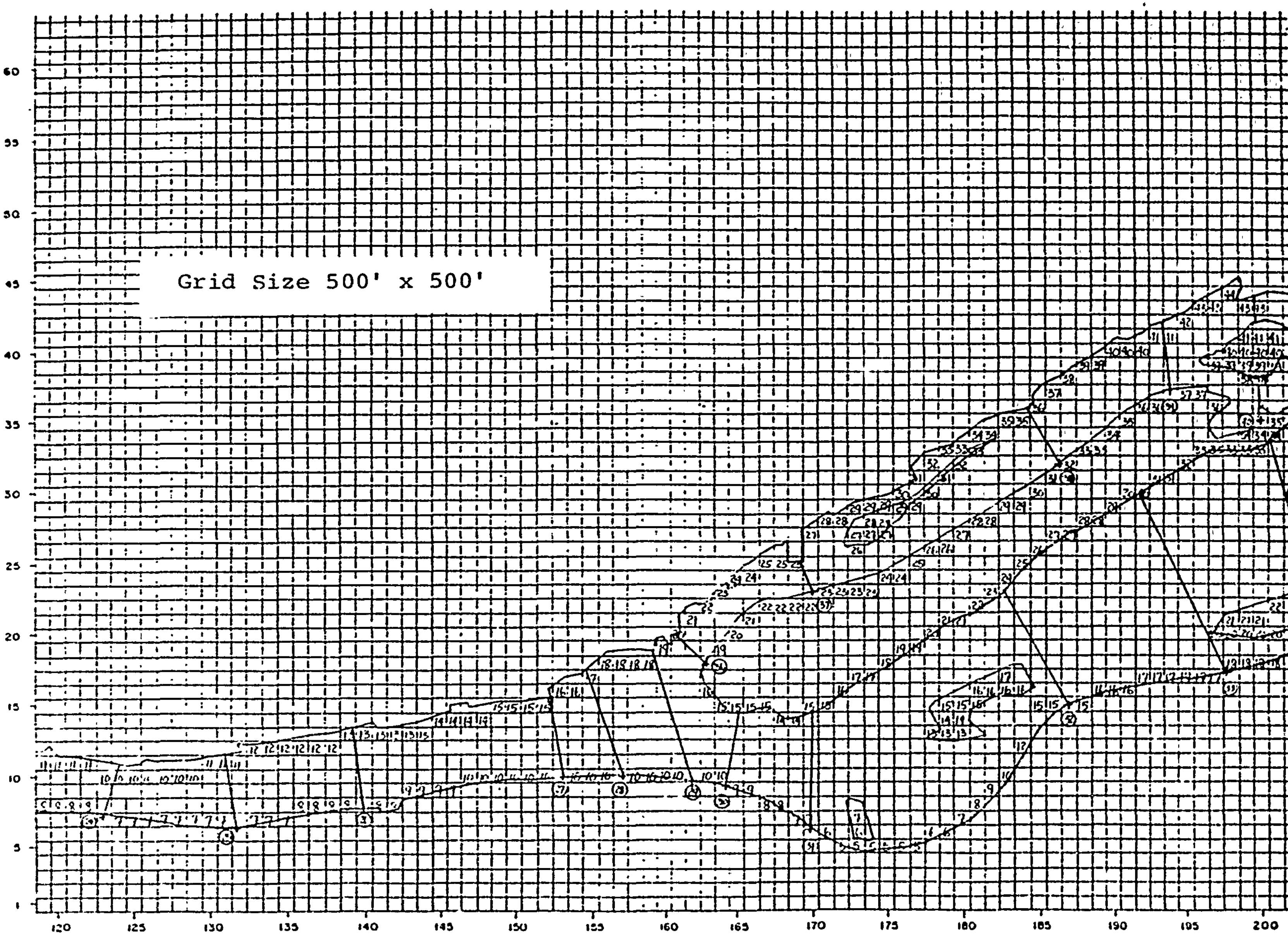
d. x *grid range 202–285,* y *grid range 64–126.*

Figure A2 (cont'd).



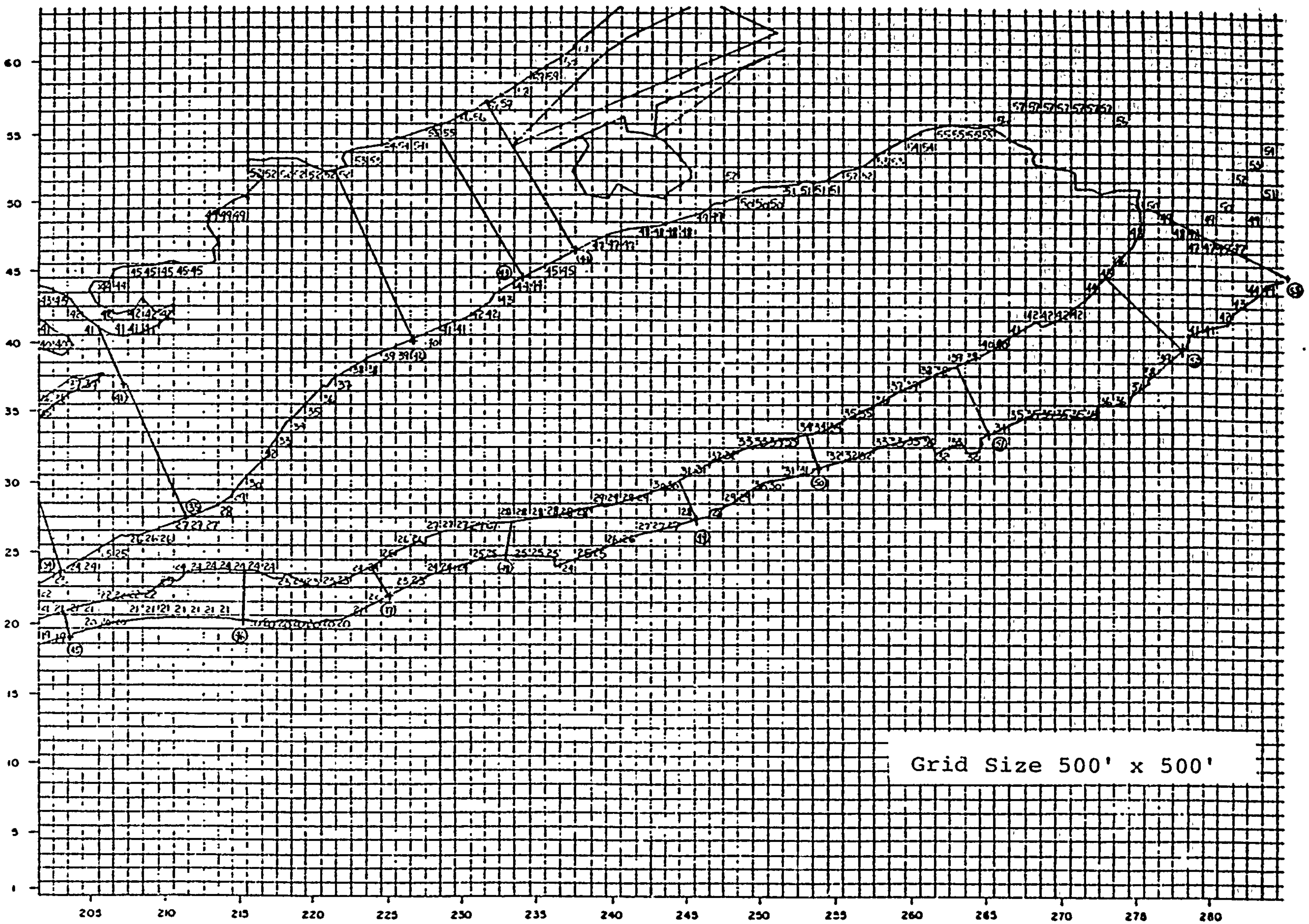
e. x grid range 36–118, y grid range 1–63.

Figure A2 (cont'd). Grid index for the Detroit River.



f. x *grid range 119–201,* y *grid range 1–63.*

Figure A2 (cont'd).



g. x grid range 202–285, y grid range 1–63.

Figure A2 (cont'd). Grid index for the Detroit River.

APPENDIX B. SAMPLE DATA FILES FOR THE LAKE ST. CLAIR–DETROIT RIVER STUDY AREA

The sample files have fictitious weather station locations.

Table B1. LDETR.GEO, Unit 1.

```
DETR  LAKE ST. CLAIR AND DETROIT RIVER
16  35  285  4000.  500.  7  -1.4E+05
2  5  8  10  15  18  22  27  29  31  33  35  41  44  50  52
  1  (250.,30500)          1.57079630  11  11   2    0
  2  (1895.4,30474.9)      1.35387330  11  12   3    6
  3  (1895.4,30474.9)      0.80316770   9  11   4    0
  4  (3572.5,28827.7)      0.57252250   9  11   5    0
  5  (4329.2,27835.3)      0.85065230   9  21   9    0
  6  (6348.3,33851.1)      0.32890491   2  11   7  888
  7  (6573.7,33287.7)      0.27566774   2  11   8    0
  8  (6880.6,30383.6)      0.19895402   2  21   9  999
  9  (5218.9,26793.0)      0.60033042  11  11  10    0
 10  (6206.0,24830.4)      0.78546520  11  12  11   16
 11  (7367.3,23785.9)      0.38429453   4  11  12    0
 12  (11648.1,18516.6)     0.89099240   4  11  13    0
 13  (16161.9,16194.4)     1.06953870   4  11  14    0
 14  (16630.9,16089.5)     1.03244550   4  11  15    0
 15  (18885.3,15317.3)     1.29700210   4  21  19    0
 16  (10645.8,26730.4)     1.50359930   7  11  17  888
 17  (15909.5,22917.5)     0.89085370   7  11  18    0
 18  (19678.2,18445.3)     0.56874187   7  21  19  999
 19  (20184.2,14800.2)     0.65250602  11  11  20    0
 20  (23601.6,12740.2)     1.01761670  11  11  21    0
 21  (27986.0,9434.1)      0.84731720  11  11  22    0
 22  (32096.4,6111.7)      1.11644090  11  11  23    0
 23  (36555.3,4153.7)      1.31789400  11  11  24    0
 24  (43737.9,3322.7)      1.29165360  11  11  25    0
 25  (48111.9,2967.3)      1.73312770  11  11  26    0
 26  (52258.0,3574.1)      1.70696930  11  11  27    0
 27  (58891.5,4663.2)      1.74159230  11  11  28    0
 28  (60821.2,4700.4)      1.89850420  11  11  29    0
 29  (63193.4,4508.6)      1.85897050  11  12  30   36
 30  (64446.6,4279.9)      1.40498040   9  11  31    0
 31  (67199.6,2882.9)      1.55881210   9  11  32    0
 32  (75744.0,7230.3)      2.07408620   9  11  33    0
 33  (81028.9,8357.1)      2.01051160   9  12  45   34
 34  (83712.4,11584.0)     1.85562200   7  11  35  888
 35  (87888.6,13541.0)     1.97159570   7  21  42    0
 36  (63732.4,8702.1)      2.37748450   2  11  37  888
 37  (67304.8,11205.3)     1.95566550   2  11  38    0
 38  (75490.2,15658.0)     2.08554860   2  11  39    0
 39  (79227.9,18354.3)     1.69594960   2  21  40    0
 40  (82248.9,17195.8)     1.63639540   2  11  41    0
 41  (85910.8,18208.0)     1.96796920   2  21  42  999
 42  (95603.0,19752.6)     1.98250300   9  11  43    0
 43  (99230.8,22002.3)     2.09447510   9  11  44    0
 44  (101000.3,23059.3)    2.10296690   9  11  43    0
 45  (84015.6,9218.3)      1.97403760   2  11  46    0
 46  (89415.8,9892.4)      1.55666850   2  11  47    0
 47  (94836.8,10752.4)     2.10658900   2  11  48    0
 48  (98678.7,12200.2)     1.41654700   2  11  49    0
 49  (105015.3,13480.9)    1.97177820   2  11  50    0
 50  (109190.4,15253.3)    1.89456780   2  11  51    0
 51  (114885.3,16482.1)    2.00199130   2  11  52    0
 52  (121352.6,19517.5)    2.37169600   2  11  53    0
 53  (125494.9,22087.9)    2.67019810   2  11  52    0
      1       17   571.71
 1375.00    6.00  1675.00   24.00  3000.00   21.00  3575.00   16.00  4000.00   23.0
 4250.00   18.00  5000.00   10.00  8500.00    9.00  9625.00   10.00 10875.00    8.0
13000.00    8.00 13250.00    6.00 15500.00    4.00 21000.00    6.00 26000.00    4.0
29000.00    3.00 37000.00    0.00
```

Table B1 (cont'd). LDETR.GEO, Unit 1.

2	16	571.71							
125.00	12.00	200.00	21.00	1500.00	27.00	2000.00	28.00	2500.00	12.0
2550.00	9.00	3125.00	6.00	4375.00	2.00	6000.00	6.00	6450.00	12.0
6625.00	19.00	7000.00	25.00	7750.00	7.00	8325.00	6.00	10500.00	2.0
11783.00	0.000								
3	10	574.87							
25.00	14.00	125.00	28.00	500.00	36.00	1000.00	37.00	1200.00	33.0
1750.00	32.00	2000.00	30.00	2250.00	10.00	3000.00	8.50	3425.00	0.0
4	10	574.94							
155.00	25.00	900.00	27.50	1025.00	36.00	1275.00	40.00	1400.00	35.5
1700.00	43.00	2125.00	30.00	2375.00	10.00	3250.00	5.00	3375.00	0.0
5	9	574.91							
50.00	12.00	125.00	20.00	750.00	21.00	1250.00	22.00	1350.00	28.0
2425.00	28.00	2525.00	5.00	3250.00	4.00	3425.00	0.00		
6	5	574.45							
75.00	12.00	175.00	22.00	250.00	27.00	825.00	27.00	1400.00	0.0
7	5	574.50							
75.00	12.00	175.00	22.00	250.00	27.00	825.00	27.00	1250.00	0.0
8	10	574.91							
80.80	11.00	141.60	26.30	197.80	28.80	373.00	29.50	627.40	30.8
759.60	30.00	1123.80	24.10	1183.60	21.10	1233.10	9.50	1322.00	0.0
9	15	574.92							
125.00	12.00	250.00	25.00	500.00	21.00	800.00	19.50	1000.00	27.5
1250.00	23.00	2050.00	22.50	2850.00	38.00	3500.00	38.00	4000.00	29.0
4250.00	43.00	4650.00	45.00	4825.00	6.50	5000.00	6.50	5100.00	0.0
10	11	574.87							
75.00	4.00	275.00	18.00	575.00	24.00	1250.00	18.00	2075.00	12.0
2825.00	27.00	3825.00	29.00	4450.00	39.00	4600.00	18.00	4675.00	2.0
5075.00	0.00								
11	7	574.82							
101.10	25.00	266.10	24.80	506.50	29.10	756.20	33.00	1222.90	31.0
1360.00	25.90	1461.00	0.00						
12	11	574.54							
25.00	12.00	75.00	25.00	475.00	23.00	575.00	12.00	800.00	6.0
1250.00	2.00	1875.00	5.00	2050.00	22.00	2550.00	27.00	2750.00	5.0
3400.00	0.00								
13	7	574.27							
87.60	22.20	159.00	26.90	1106.90	20.90	1092.90	26.40	1997.50	23.4
2073.60	11.70	2110.70	0.00						
14	10	574.57							
1.90	9.50	135.00	25.40	550.10	30.50	695.30	24.30	882.50	29.0
1000.00	20.00	1373.70	22.30	1691.80	26.30	1843.60	21.10	1923.20	0.0
15	11	574.16							
24.20	19.70	607.00	21.90	1004.50	28.50	1207.70	10.00	1388.10	32.7
1598.30	27.00	1684.20	19.90	1862.20	12.90	1891.40	7.30	2194.30	5.9
2203.80	0.00								
16	12	574.85							
125.00	25.50	250.00	35.00	350.00	33.00	680.00	47.50	825.00	42.0
1250.00	46.00	1525.00	35.00	1625.00	35.00	1825.00	9.00	2125.00	7.5
2533.00	9.00	2550.00	0.00						
17	8	574.18							
108.80	31.40	317.30	39.10	529.20	35.30	754.70	39.60	1003.90	36.6
1660.30	42.20	1831.30	24.10	1920.80	0.00				
18	12	574.47							
30.00	4.50	63.00	13.50	250.00	14.50	475.00	41.50	563.00	32.0
1125.00	32.50	1375.00	40.50	1625.00	42.50	1750.00	34.50	1825.00	38.0
1950.00	23.00	2000.00	0.00						
19	15	574.53							
125.00	12.00	375.00	18.00	425.00	25.00	1000.00	35.00	1250.00	37.0
1375.00	37.00	1500.00	9.00	1725.00	9.00	1850.00	25.00	2000.00	37.0
2375.00	29.00	2750.00	28.00	3125.00	32.00	3500.00	35.00	3750.00	0.0
20	9	574.59							
10.00	27.00	550.00	28.00	625.00	37.00	1375.00	35.50	1750.00	36.0
2125.00	48.00	2310.00	43.00	2625.00	38.00	2910.00	0.00		
21	8	574.02							
117.60	26.20	368.50	21.70	634.20	31.80	811.10	50.80	1337.70	38.6
1657.20	48.00	2223.70	40.50	2372.80	0.00				
22	13	574.40							
25.00	23.00	125.00	27.50	200.00	23.80	475.00	34.00	600.00	29.5

Table B1 (cont'd).

750.00	44.50	1000.00	49.80	1250.00	43.00	1600.00	47.40	1750.00	36.0
2000.00	45.00	2125.00	42.00	2250.00	0.00				
23	9	574.50							
125.00	18.00	175.00	29.00	375.00	41.00	1375.00	45.00	1500.00	47.0
1625.00	32.00	1800.00	18.00	1875.00	6.00	2050.00	0.00		
24	7	573.60							
197.00	37.80	451.10	46.20	717.30	46.90	1186.50	39.80	1593.60	42.8
1673.60	39.30	1903.10	0.00						
25	7	573.90							
25.00	28.00	125.00	38.00	1000.00	38.00	1500.00	31.00	2250.00	32.0
2500.00	27.00	2550.00	0.00						
26	8	574.19							
25.00	8.50	510.00	45.00	1120.00	37.50	2075.00	34.75	2375.00	37.5
2600.00	33.75	2710.00	8.00	2825.00	0.00				
27	9	574.14							
25.00	19.00	125.00	25.00	300.00	40.00	1000.00	39.00	1500.00	32.0
1750.00	36.00	2375.00	36.00	2625.00	24.00	2650.00	0.00		
28	11	574.12							
250.00	38.30	680.00	43.20	1125.00	36.00	1485.00	35.00	1750.00	40.8
2090.00	37.20	2500.00	37.50	2850.00	10.00	3320.00	5.20	3750.00	8.0
4250.00	0.00								
29	9	573.97							
175.00	34.00	1050.00	38.00	2175.00	28.00	2500.00	18.00	2675.00	25.0
3300.00	27.00	3425.00	4.00	4425.00	3.00	4675.00	0.00		
30	13	573.32							
185.00	23.50	375.00	40.00	500.00	41.00	625.00	40.20	850.00	35.5
1150.00	37.00	1500.00	35.30	1650.00	38.20	2000.00	29.50	2125.00	8.5
2310.00	4.80	2450.00	6.80	2510.00	0.00				
31	11	573.40							
27.10	3.20	230.90	6.00	450.10	20.00	835.60	30.00	1548.30	34.0
1842.40	45.50	2330.90	31.00	2586.60	34.40	2864.60	8.10	3354.00	6.5
3400.00	0.00								
32	14	573.39							
117.30	35.20	222.90	37.20	803.50	30.00	996.90	10.90	1503.20	6.0
1829.30	10.00	1975.90	31.00	2550.50	39.20	3196.90	35.00	3392.00	16.8
4179.00	4.80	4207.60	9.00	4276.50	8.20	4776.60	0.00		
33	19	573.51							
32.80	17.80	115.10	34.60	327.40	34.30	593.00	36.00	864.00	9.4
1148.70	6.40	1198.30	9.50	1254.40	0.00	1300.00	0.00	1337.40	7.9
2000.90	32.80	2389.90	7.20	2443.4	6.20	2983.60	13.70	3234.50	38.0
4076.00	38.00	4409.10	9.30	6203.8	6.00	6715.40	6.40	6760.70	0.0
34	12	573.75							
300.00	31.00	500.00	31.00	780.00	4.50	1310.00	4.60	1790.00	35.0
2090.00	37.00	2900.00	35.00	3250.00	36.00	3680.00	7.20	5600.00	6.8
5650.00	9.00	5750.00	0.00						
35	10	572.40							
450.00	6.00	575.00	28.00	1250.00	36.00	1750.00	33.00	2700.00	28.0
2725.00	18.00	2825.00	5.00	4500.00	3.00	5000.00	2.00	5025.00	0.0
36	8	573.73							
120.00	9.10	174.00	19.60	461.30	34.90	851.00	32.00	986.20	21.9
1040.00	13.40	1106.00	5.30	1175.30	0.00				
37	5	573.30							
24.40	14.40	573.00	33.40	722.30	31.00	896.10	16.00	975.80	0.0
38	8	573.40							
198.80	23.60	501.90	25.50	853.90	24.10	952.30	8.60	1887.40	7.0
1980.10	25.80	2265.30	21.40	2428.00	0.00				
39	9	573.68							
92.20	24.90	301.20	31.00	445.60	28.10	680.60	35.20	969.40	22.0
1051.70	8.10	1707.00	7.20	2242.90	4.30	2375.20	0.00		
40	11	573.76							
1500.00	0.01	1625.00	25.00	2000.00	25.00	2100.00	2.00	2300.00	0.0
3750.00	0.00	3825.00	5.00	3900.00	32.00	4225.00	32.00	4375.00	2.0
4675.00	0.00								
41	10	573.83							
25.00	2.00	625.00	1.00	750.00	27.00	1125.00	27.00	1175.00	23.0
1250.00	30.00	1750.00	32.00	1925.00	6.00	2125.00	2.00	2150.00	0.0
42	17	573.91							
50.00	3.00	475.00	3.00	1000.00	26.50	2000.00	27.20	2100.00	35.0

Table B1 (cont'd). LDETR.GEO, Unit 1.

```
2800.00     35.00 3100.00    24.80 3300.00    32.00 3750.00    30.00 4250.00    33.0
4500.00     27.80 5100.00    28.00 5500.00     9.00 5900.00     7.50 6900.00     8.0
7000.00     12.00 7100.00     0.00
     43        15  572.64
  72.80      3.30  292.90     6.40 2564.00    10.70 2709.50    26.60 3745.50    24.4
3771.70     28.70 4424.00    36.20 4509.30    27.30 4996.00    25.00 5150.60    22.2
5327.90     27.80 5482.00    28.30 5796.10    11.00 6110.80    13.10 6345.80     0.0
     44        12  572.70
 575.00      6.00  750.00     6.00 1000.00     5.00 2750.00     3.00 3175.00     6.0
3375.00     18.00 4300.00    18.00 4375.00    27.00 4950.00    27.00 5400.00    18.0
5900.00      6.00 6050.00     0.00
     45         8  573.76
  16.70      4.70  129.10    30.60  283.70    36.10  474.10    36.90  657.20    30.0
 812.00      8.70  866.90     7.40  898.10     0.00
     46        10  573.23
   4.00      3.00   44.90     3.50  243.80    32.30  536.30    33.00  779.30    31.4
 992.50      6.70 1152.00     4.30 1849.90     3.30 1940.20     1.90 2002.80     0.0
     47        11  573.45
  55.40     19.00  277.50    18.00  433.60    23.00  460.00    15.10  501.60    32.6
 772.50     34.60  822.90    21.00  848.20    25.30  978.40    10.50 1095.20     7.5
1246.00      0.00
     48        10  572.93
  15.70      2.20   70.40     2.50  239.90    21.90  439.70     9.50  590.60     9.7
 876.40     27.30 1237.90    24.30 1376.90     7.70 1496.30     4.50 1523.20     0.0
     49        10  573.12
  47.90      3.60   99.50    23.90  636.30    16.10  756.00    19.90  837.70    17.6
 981.80     29.60 1143.90    26.50 1165.10    20.00 1379.10    14.70 1425.00     0.0
     50         4  572.83
  31.30     25.20  209.10    29.00  990.20    27.10 1145.90     0.00
     51        10  572.82
 226.10      7.50  274.60     6.50  766.00     7.80 1245.50    21.80 1345.30    19.1
1805.80     15.70 1921.90    20.40 2395.50    15.50 2471.90     9.80 2638.50     0.0
     52        18  572.68
 319.50     19.60  405.70     8.20  559.00     9.30  881.80    22.80 1033.40     7.9
1508.20      5.40 1676.10    21.90 2128.40    15.00 2194.10     9.00 2466.20     9.7
2542.30     17.20 2646.40    13.60 2708.50     7.80 2770.80     7.10 3015.40     1.9
3208.80      5.90 3431.90     7.20 3674.50     0.00
     53        11  572.60
 875.00      4.00 1000.00    18.00 2000.00    18.00 2175.00     5.00 2550.00     0.0
4125.00      0.00 4625.00     2.00 4875.00    14.00 5125.00    14.00 5500.00     4.0
6500.00      0.00
  1    10    10    10    10
  2     7    11     0     0
  3     5    11     0     0
  4     5    11     0     0
  5     4    10     0     0
  6     4     9     0     0
  7     4    12    10    11
  8     3    12    10    11
  9     2    31    13    29
 10     2    32    15    26
 11     2    32    15    25
 12     2    32    20    22
 13     6    33    20    20
 14     6    34    15    15
 15     7    35     0     0
 16     5    36     0     0
 17     4    36     0     0
 18     4    37     0     0
 19     4    37     0     0
 20     4    37     0     0
 21     4    37     0     0
 22     4    37     0     0
 23     4    36     0     0
 24     5    36     0     0
 25     5    34     0     0
 26     6    31     0     0
 27     7    30     0     0
 28     8    29     0     0
```

Table B1 (cont'd).

29	8	28	0	0
30	8	27	0	0
31	9	26	0	0
32	9	25	0	0
33	9	23	0	0
34	8	21	0	0
35	8	19	0	0
36	62	132	0	0
37	62	125	0	0
38	62	122	0	0
39	62	114	0	0
40	61	108	0	0
41	60	104	0	0
42	59	99	0	0
43	58	92	0	0
44	57	86	67	68
45	56	83	66	69
46	54	82	66	69
47	53	80	65	69
48	52	77	63	68
49	51	71	61	62
50	49	69	0	0
51	47	67	0	0
52	45	61	51	53
53	43	60	49	54
54	42	59	47	54
55	41	58	45	53
56	40	58	44	53
57	39	58	44	53
58	39	58	44	53
59	38	58	43	53
60	37	58	43	53
61	36	58	43	51
62	35	57	43	50
63	35	57	43	50
64	35	55	42	48
65	34	54	42	47
66	34	52	41	47
67	33	51	40	46
68	33	50	39	45
69	33	49	38	44
70	33	49	37	43
71	33	48	36	43
72	32	47	36	41
73	32	46	36	40
74	31	45	36	38
75	31	44	36	36
76	30	43	0	0
77	30	41	0	0
78	29	39	0	0
79	29	37	0	0
80	28	36	0	0
81	27	35	0	0
82	27	34	0	0
83	26	33	0	0
84	25	32	0	0
85	25	31	0	0
86	24	30	0	0
87	23	29	0	0
88	22	28	0	0
89	22	27	0	0
90	21	26	0	0
91	20	25	0	0
92	19	24	0	0
93	18	23	0	0
94	18	23	0	0
95	17	22	0	0
96	16	21	0	0
97	15	20	0	0

Table B1 (cont'd). LDETR.GEO, Unit 1.

98	14	19	0	0
99	13	18	0	0
100	13	17	0	0
101	12	17	0	0
102	12	16	0	0
103	12	15	0	0
104	11	15	0	0
105	11	14	0	0
106	10	14	0	0
107	10	13	0	0
108	9	13	0	0
109	9	12	0	0
110	9	12	0	0
111	9	12	0	0
112	8	12	0	0
113	8	11	0	0
114	8	11	0	0
115	8	11	0	0
116	8	11	0	0
117	8	11	0	0
118	8	11	0	0
119	8	11	0	0
120	8	11	0	0
121	8	11	0	0
122	8	11	0	0
123	7	10	0	0
124	7	10	0	0
125	7	10	0	0
126	7	10	0	0
127	7	10	0	0
128	7	10	0	0
129	7	10	0	0
130	7	11	0	0
131	7	11	0	0
132	7	11	0	0
133	7	12	0	0
134	7	12	0	0
135	7	12	0	0
136	8	12	0	0
137	8	12	0	0
138	8	12	0	0
139	8	13	0	0
140	8	13	0	0
141	8	13	0	0
142	8	13	0	0
143	9	13	0	0
144	9	13	0	0
145	9	14	0	0
146	9	14	0	0
147	10	14	0	0
148	10	14	0	0
149	10	15	0	0
150	10	15	0	0
151	10	15	0	0
152	10	15	0	0
153	10	16	0	0
154	10	16	0	0
155	10	17	0	0
156	10	18	0	0
157	10	18	0	0
158	10	18	0	0
159	10	18	0	0
160	10	19	0	0
161	10	20	0	0
162	10	21	0	0
163	10	22	16	18
164	10	23	15	19
165	9	24	15	20
166	9	24	15	21
167	8	25	15	22

Table B1 (cont'd).

168	8	25	14	22
169	7	25	14	22
170	7	27	15	22
171	6	28	15	23
172	5	28	16	23
173	5	29	17	23
174	5	29	17	23
175	5	29	18	24
176	5	30	19	24
177	5	31	19	25
178	6	32	20	26
179	6	33	21	26
180	7	33	21	27
181	8	34	22	28
182	9	34	23	28
183	10	35	24	29
184	12	35	25	29
185	15	36	26	30
186	15	37	27	31
187	15	38	27	32
188	15	39	28	33
190	16	40	29	34
191	16	40	30	35
192	17	40	30	36
193	17	41	31	36
194	17	41	31	37
195	17	42	32	37
196	17	43	33	37
197	17	43	20	20
198	18	44	20	21
199	18	43	20	21
200	18	43	20	21
201	18	43	20	22
202	19	43	21	22
203	19	43	21	23
204	19	42	21	24
205	20	41	21	24
206	20	44	22	25
207	20	44	22	25
208	21	45	22	26
209	21	45	22	26
210	21	45	23	26
211	21	45	24	27
212	21	45	24	27
213	21	49	24	27
214	21	49	24	28
215	20	49	24	29
216	20	52	24	30
217	20	52	24	32
218	20	52	23	33
219	20	52	23	34
220	20	52	23	35
221	20	52	23	36
222	20	52	23	37
223	21	53	24	38
224	22	53	24	38
225	22	54	25	39
226	23	54	26	39
227	23	54	26	40
228	24	55	27	40
229	24	55	27	41
230	24	56	27	41
231	25	56	27	42
232	25	57	27	42
233	25	57	28	43
234	25	58	28	44
235	25	59	28	44
236	25	59	28	45

Table B1 (cont'd). LDETR.GEO, Unit 1.

237	24	60	28	45
238	25	61	28	46
239	25	47	29	47
240	26	47	29	47
241	26	47	29	47
242	27	48	29	48
243	27	48	30	48
244	27	48	30	48
245	28	48	31	48
246	28	49	31	49
247	28	49	32	49
248	29	52	32	52
249	29	50	33	50
250	30	50	33	50
251	30	50	33	50
252	31	51	33	51
253	31	51	34	51
254	31	51	34	51
255	32	51	34	51
256	32	52	35	52
257	32	52	35	52
258	33	53	36	53
259	33	53	37	53
260	33	54	37	54
261	33	54	38	54
262	32	55	38	55
263	33	55	39	55
264	32	55	39	55
265	34	55	40	55
266	34	56	40	56
267	35	57	41	57
268	35	57	42	57
269	35	57	42	57
270	35	57	42	57
271	35	57	42	57
272	35	57	44	57
273	36	57	45	57
274	36	56	46	56
275	37	50	48	50
276	38	50	0	0
277	39	49	0	0
278	40	48	0	0
279	41	48	47	48
280	41	49	47	49
281	42	50	47	50
282	43	52	47	52
283	44	53	49	53
284	44	54	51	54
285	45	55	52	55

76
9 10
11 12
11 13
10 13
10 29
12 15
12 16
12 25
13 15
173 6
173 7
173 26
173 27
174 27
174 28
175 27
175 28
176 29

Table B1 (cont'd).

177	29
178	13
178	30
179	13
179	14
179	15
179	31
180	13
180	14
180	15
180	32
181	15
181	16
181	33
182	16
183	16
183	17
184	16
197	33
197	36
197	39
198	33
198	39
198	40
199	33
199	34
199	38
199	39
199	40
199	41
200	33
200	34
200	35
200	38
200	39
200	40
200	41
201	34
201	35
201	39
201	40
201	41
202	35
202	36
202	40
202	41
203	36
203	40
204	37
205	37
206	41
206	42
207	41
208	41
208	42
209	41
209	42
210	42
0	

Table B2. LDETR.ICE, Unit 5.

```
0.035        12.5
1   1
 2   7  35  19
0.5
```

Table B3. LDETR.FLW, Unit 7.

```
  6.0
573.72   149190.
573.61   149180.
573.61   184150.
573.61   120810.
573.46   120810.
573.46   184140.
573.14   184140.
573.01   184140.
573.01   153050.
572.67   153050.
572.67   115400.
572.31   115400.
572.31   146450.
573.69    34970.
573.61    34970.
573.61    63340.
573.46    63340.
573.01    31070.
572.31    31050.
572.67    37640.
571.97    37640.
571.35    37630.
  1
   2 OPEN
573.72   149190.
573.61   149180.
573.61   184150.
573.61   120810.
573.46   120810.
573.46   184140.
573.14   184140.
573.01   184140.
573.01   153050.
572.67   153050.
572.67   115400.
572.31   115400.
572.31   146450.
573.69    34970.
573.61    34970.
573.61    63340.
573.46    63340.
573.01    31070.
572.31    31050.
572.67    37640.
571.97    37640.
571.35    37630.
  1
   2 OPEN
```

Table B4. LDETR.BND, Unit 8.

(These are approximate values based on engineering judgment to illustrate the model capability).

1	1	285	10
2	1	285	10
3	7	14	10
3	44	49	10
3	52	75	10
3	163	275	10
3	279	285	10
4	7	14	10
4	44	49	10
4	52	75	10
4	163	275	10
4	279	285	10
0	0	0	0

Table B5. LDETR.SPL, Unit 12.

```
Fuel Oil No. 2
6.0    3   0   0   1   0   10.   -1.0    -1.0
500  10000.  900.  0.84  1.411E-5  2.06E-3 1.14 .98  1.6  1.39,1.39,1.43
-7999.    42000.    .7063E-02  .1873E-02   7.88   465.0
2.933  0.0   50.0
2.933  0.0   50.0
2.933  0.0   50.0
2.933  0.0   50.0
2.933  0.0   50.0
2.933  0.0   50.0
2.933  0.0   50.0
2.933  0.0   50.0
2.933  0.0   50.0
```

Table B6. LAKEWIND.DAT, Unit 10

0.	42.42	82.42	30.	64.	54.	15.0	180.
3.	42.42	82.42	30.	64.	54.	15.0	180.
6.	42.42	82.42	10.	65.	54.	15.0	150.
9.	42.50	82.58	10.	66.	54.	12.0	180.
12.	42.50	82.58	10.	66.	55.	10.0	270.
-1.							

Table B7. LAKEBATH.DAT, Unit 13.

```
LAKE ST. CLAIR BATHYMETRY
   36    38   42.3041534   82.9315796 4000     19      1 -2.24 39.677 10.087-120.06
   0.822690E+02   -0.418687E+01   -0.892958E+00    0.549244E+00
   0.204351E+01    0.110232E+03    0.182918E+00    0.235336E+00
   0.121387E-01    0.462637E-03    0.110856E-05   -0.102938E-05
  -0.313049E-03    0.905963E-02   -0.238882E-06   -0.279918E-06
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    3    5    4    3    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    3    5    6    5    4    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    5    7
    7    8    7    7    5    3    0    0    0    0    6    8    6    6    5    5    4    0    0.
    0    0    0    0    0    0    0    0    0    0    0    0    0    2    4    8    8   10   10
    9    9    6    4    0    0    0    3   10   10   10   12   11   11    9    7    5    0    0
    0    0    0    0    0    0    0    0    0    0    0    6    8    9    9   10   10   10    8
    9    6    3    4    0    5   11   12   11   10   12   11   11   10    9    8    0    0    0
    0    0    0    0    0    0    0    0    3    9    9    6    4    5    8    9    9   10    9
    6    4    5    5    9   12   13   13   13   13   13   13   12    8    2    0    0    0    0
    0    0    0    0    0    0    3    9    6    1    2    3    2    2    3    6    8    7    6
    7    9   12   13   13   14   14   14   14   14   14   13   14   12    6    2    0    0    0
    2    3    0    0    1    6    1    2    2    1    2    1    1    1    3    6    9   10   11
   13   14   14   15   15   15   15   14   14   14   14   13   13   12   12   11   10    8   15
    0    0    3    5    1    2    0    0    0    0    2    1    2    4    6   10   12   13  .15
   14   14   16   15   14   15   15   15   15   14   14   14   13   13   13   12   12    0    0
    2    2    1    0    0    0    0    1    3    3    3    2    1    7   14   15   14   17   16
   17   17   16   15   15   15   16   15   12   13   10    8   10   10   10    0    0    0    0
    0    0    0    1    1    1    2    0    [illegible]    1    2    3   13   15   14   14   17   16  .15
   15   16   18   16   16   14   12   13   10   12   11   10    7    0    0    0    0    0    0
    0    0    0    0    0    0    1    2    2    3   12   14   15   16   16   17   17   16   17
   16   16   15   14   15   13   12   13   12   10    6    0    0    0    0    0    0    0    0
    0    0    1    1    2    2    2    2   14   14   15   14   16   15   16   17   17   18   16
   14   17   13   15   15   13   11   10    7    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    1   10   15   16   16   17   16   17   19   17   19   18   17   12
   14   15   14   13   12    9    7    0    0    0    0    0    0    0    0    0    0    0    0
    0    1    2    6   13   15   17   17   17   17   17   17   19   17   18   17   16   16   15
   14   11   11    8    5    0    0    0    0    0    0    0    0    0    0    0    0    1    1
    7   12   14   16   17   17   17   18   18   19   18   18   17   17   17   16   15   14   13
   12   10    5    0    0    0    0    0    0    0    0    0    0    0    0    1    1    6   12
   13   15   16   17   18   18   18   18   18   19   18   16   17   15   15   15   13   10    8
    3    0    0    0    0    0    0    0    0    0    0    0    0    1    1    3    7   12   13
   16   17   18   18   18   18   17   17   17   17   16   16   16   15   13   12   10    3    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    2    2   10   12   17   18
   18   17   17   17   16   17   17   15   16   16   16   15   13   11    5    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    2    1    1    6   13   17   18   17   17
   17   16   16   16   16   16   17   16   15   13   12   10    4    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    2    2    2    6   13   17   17   17   17   17   17
   17   15   16   15   15   15   15   14   11    9    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    1    3    4    2    6   14   17   17   17   18   17   16   15   16
   15   12   15   15   13   11    9    2    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    2    3    3    4    6   14   16   16   16   17   17   16   15   16   15   15
   14   11   12   10    5    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    1    3    2    9   13   14   15   17   17   17   15   15   15   15   15   13   12
    9    6    2    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    1
    2    3    4   11   12   14   15   15   17   17   16   15   15   15   14   13   11    9    2
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    1    1    3    2    4
    3   11   11   13   15   17   17   16   15   15   15   14   12   12    9    6    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    0    1    1    3    2    3    6   11
   10   15   15   16   17   17   16   15   14   13   11    9    6    0    0    0    0    0    0
    0    0    0    0    0    0    0    0    0    0    0    2    3    3    3    5   10   10   14
   14   15   16   16   15   13   12   10    8    3    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    0    0    2    3    4    5    5    3    6   10   11   13   15   17
   16   15   13   10    9    7    1    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    1    2    1    2    6    7    9   10   10   11   17   16   15   15
   13   10    7    3    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    1    1    1    6   10   10   10   12   12   16   17   15   13   12    9
    4    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    0    0    0    0    0    1    1    6   11   11   12   17   17   13   13   11    8    2    0
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
```

Table B7(cont'd).

0	0	0	0	2	6	13	11	11	17	13	12	12	11	6	2	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	2	5	12	12	12	11	11	9	4	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	1	10	10	10	9	5	4	2	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	2	2	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1.																	

APPENDIX C. RESULTS OF SAMPLE SIMULATIONS

The following figures represent selected output and graphics for two sample runs of LROSS. The first sample run (Fig. C1) is for an instantaneous spill near the lake–river interface. The second one (Fig. C2) is on the opposite side of Lake St. Clair where the St. Clair River discharges into the lake. (The graphical plots are not a direct form of output from the oil spill model. Rather, they are indirectly generated from the shoreline data in file RIVLAK.SHO and the particle locations in file D.OILSP.) The output should be self-explanatory with the aid of the figure captions.

```
       Lake St. Clair and Detroit River

    **************************
    *  INSTANTANEOUS SPILL   *
    *          AT            *
    *    -7999., 42000.      *
    **************************


SIMULATION PERIOD  =   6.0 Hrs


Characteristics of spill

No. of particles            :  500
Oil spilled                 :  10000. gals of Fuel Oil No. 2
DT for spill simulation     :    900. Secs.
Specific gravity of oil     :    0.84 (API index = 37.0)
Kinematic Visco. of Water   :0.1411E-04 sq ft/sec
Surafce Tension             :0.2060E-02 lbs/ft


        Spreading Coefficients
   K2i   K2v   K2t   c10   c20   c30
  1.14  0.98  1.60  1.39  1.39  1.43

Molar volume                :0.7063E-02 cu ft/mol
Solubility of fresh oil     :0.1873E-02 lbs/cu ft
Viscosity of Oil            :    0.84 lbs/ft-sec
Manning s Roughness of Ice  :   0.035

          Surface Diffusion
  LAKE - Default formulation is used
  RIVER- Default formulation is used

API option is not selected . Evap. constants are  C = 7.88   TO = 465.0

Time step for river flow computation =   6.00Hrs
```

a. Description of spill type and locations, oil properties and various coefficients.

Figure C1 First simulation.

```
?pen Water Conditions exist in the river

Flow and Discharge Conditions in the River
 Branch   Q (cfs)    Stage (ft)
    1      184160.     573.72
    2      149190.     573.72
    3       34970.     573.69
    4      184150.     573.61
    5       63340.     573.61
    6      120810.     573.61
    7      184140.     573.46
    8      184140.     573.14
    9      194140.     573.01
   10      153050.     573.01
   11      153050.     572.67
   12      115400.     572.67
   13       31070.     573.01
   14      146470.     572.31
   15       37640.     572.67
   16       37640.     571.97
Open Water conditions exist in the lake

Meteorological Station Data Used in Lake Circulation Model
     Time   Lat.  Long. Height  T-air  T-H2O    Wind
      hrs    deg    deg    ft      F      F    mph  deg

      0.0  42.42  82.42  30.0    50.0  54.0   2.0   0.0

      3.0  42.42  82.42  30.0    50.0  54.0   2.0   0.0
```

b. Stage and discharge at river branches and meteorological data.

```
Time =   0.25 Hrs -- Wind :mag=  2.0 mph, dir =  0.0 deg   -- Air Temp= 50.0 F
Spill center after advection=  -7378., 41536. (ft)
Volume per particle          =  20.000 gals

     Slick condition during this time step

Slick information by pie / strip
Pie  No. of particles  Mean radius(ft)
 1         59              90.
 2         77              93.
 3         60              90.
 4         53              89
 5         57              90.
 6         44              88.
 7         61              91.
 8         49              90.
      Slick condition at the end of this time step

Fraction Evaporated = .60670E-03
Amount Dissolved (gals)      : This Step = .27559E-01 Total = .27559E-01
```

c. Spill information at t = 15 min.

Figure C1 (cont'd). First simulation.

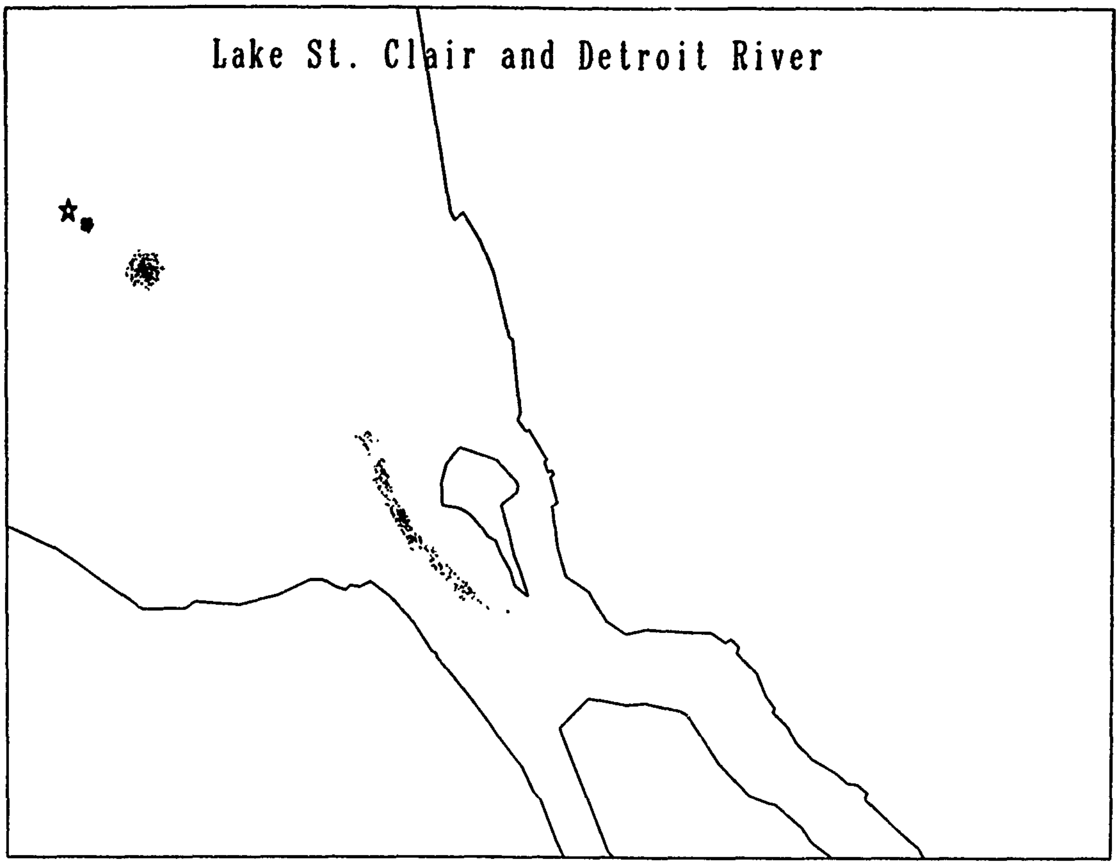
```
Time =   1.00 Hrs -- Wind :mag=  2.0 mph, dir =  0.0 deg   -- Air Temp= 50.0 F
Spill center after advection=  -5518., 40153. (ft)
Volume per particle          =  19.878 gals

     Slick condition during this time step

Slick information by pie / strip
Pie  No. of particles  Mean radius(ft)
 1        64              291.
 2        66              281.
 3        58              262.
 4        62              280.
 5        59              276.
 6        56              263.
 7        71              274.
 8        53              288.
      Slick condition at the end of this time step

 Fraction Evaporated = .14277E-01
 Amount Dissolved (gals)       : This Step = .37287     Total = .64506
```

d. Spill information at t = 1 hr.

```
Time =   4.00 Hrs -- Wind :mag=  2.0 mph, dir =  0.0 deg   -- Air Temp= 50.0 F
Spill center after advection=   3168., 32298. (ft)
Volume per particle          =  15.189 gals

     Slick condition during this time step

Slick information by pie / strip
Strip  Particles  -Le(ft)  X-mean  Le(ft)
-124        3       -237.     0.      0.
-123        6       -111.     0.     79.
-122       12        -64.     0.     94.
-121       42       -182.     0.     65.
-120       18       -108.     0.     76.
-119       34        -86.     0.    120.
-118       19        -76.     0.     94.
-117       34       -134.     0.     80.
-116       57        -73.     0.     97.
-115      106        -88.     0.     88.
-114       34        -57.     0.    164.
-113       38       -142.     0.    102.
-112       47       -154.     0.     89.
-111       13        -99.     0.     95.
-110       25        -48.     0.    229.
-109       12        -72.     0.    227.

     Slick condition at the end of this time step

Fraction Evaporated = .24958
Amount Dissolved (gals)       : This Step = 2.4525     Total = 27.238
```

e. Spill information at t = 4 hr.

Figure C1 (cont'd).



f. Plot of slick locations at t = 15 min, 1 hr and 4 hr. The figure ranges from –10,000 to 26,000 in the x direction and 22,000 to 48,280 in the y direction.

Figure C1 (cont'd). First simulation.

```
       Lake St. Clair and Detroit River

   **************************
   *   CONTINUOUS SPILL     *
   *          AT            *
   *    -91000., 51900.     *
   *     FOR   60. min.     *
   **************************


SIMULATION PERIOD  =   6.0 Hrs


Characteristics of spill

No. of particles           :  500
Oil spilled                :  10000. gals of Fuel Oil No. 2
DT for spill simulation    :    900. Secs.
Specific gravity of oil    :    0.84 (API index = 37.0)
Kinematic Visco. of Water  :0.1411E-04 sq ft/sec
Surafce Tension            :0.2060E-02 lbs/ft



       Spreading Coefficients
  K2i   K2v   K2t   c10   c20   c30
 1.14  0.98  1.60  1.39  1.39  1.43

Molar volume               :0.7063E-02 cu ft/mol
Solubility of fresh oil    :0.1873E-02 lbs/cu ft
Viscosity of Oil           :    0.84  lbs/ft-sec
Manning s Roughness of Ice :    0.035

         Surface Diffusion
   LAKE - Default formulation is used
   RIVER- Default formulation is used

  API option is not selected . Evap. constants are  C = 7.88   T0 = 465.0

  Time step for river flow computation =   6.00Hrs
```

a. Description of spill type and location, oil properties and various coefficients.

Figure C2. Second simulation.

```
Open Water Conditions exist in the river

Flow and Discharge Conditions in the River
 Branch   Q (cfs)   Stage (ft)
    1     169740.     573.26
    2     132690.     573.26
    3      37050.     573.20
    4     169740.     573.10
    5      51850.     573.10
    6     117890.     573.10
    7     169750.     573.00
    8     169750.     572.78
    9     169760.     572.63
   10     142660.     572.63
   11     142660.     572.51
   12     108140.     572.51
   13      27100.     572.62
   14     135240.     572.29
   15      34520.     572.51
   16      34530.     571.98

          No. of Ice Covered Regions in the Lake = 1
      Region    from X,Y Grid to X,Y Grid  Ice Thic(ft)
        1            15,  7       15, 20       0.10

Meteorological Station Data Used in Lake Circulation Model
      Time   Lat.  Long. Height  T-air  T-H2O    Wind
       hrs   deg    deg    ft      F      F    mph  deg

       0.0  42.42  82.42  30.0    40.0  32.0   4.0   0.0
       3.0  42.42  82.42  30.0    40.0  32.0   4.0   0.0
```

b. Stage and discharge at river branches and meteorological data.

Figure C2 (cont'd). Second simulation.

Time = 1.00 Hrs -- Wind :mag= 4.0 mph, dir = 0.0 deg -- Air Temp= 40.0 F
Spill center after advection= -90336., 50086. (ft)
Volume per particle = 19.145 gals

Slick condition during this time step

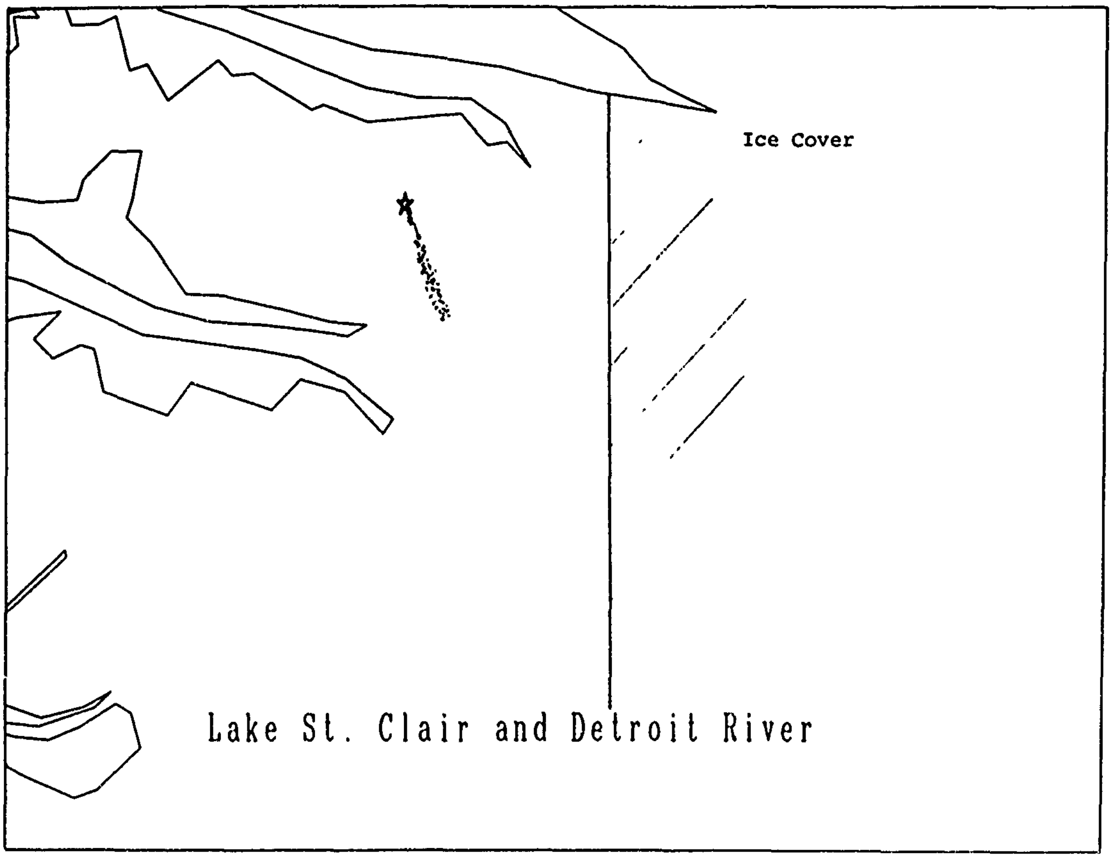
Slick information by pie / strip

Strip	Particles	-Le(ft)	X-mean	Le(ft)
56	23	-36.	0.	126.
57	64	-78.	0.	132.
58	67	-101.	0.	98.
59	63	-95.	0.	100.
60	63	-93.	0.	63.
61	67	-76.	0.	70.
62	64	-130.	0.	0.
63	65	-50.	0.	41.
64	24	-37.	0.	32.

Slick condition at the end of this time step

Fraction Evaporated = .64919E-01
Amount Dissolved (gals) : This Step = 1.1729 Total = 2.9714

c. Spill information at t = *1 hr.*



d. Plot of slick location corresponding to Figure C2c.

Figure C2 (cont'd).

Time = 2.00 Hrs -- Wind :mag= 4.0 mph, dir = 0.0 deg -- Air Temp= 40.0 F
Spill center after advection= -88782., 46501. (ft)
Volume per particle = 17.378 gals

Slick condition during this time step

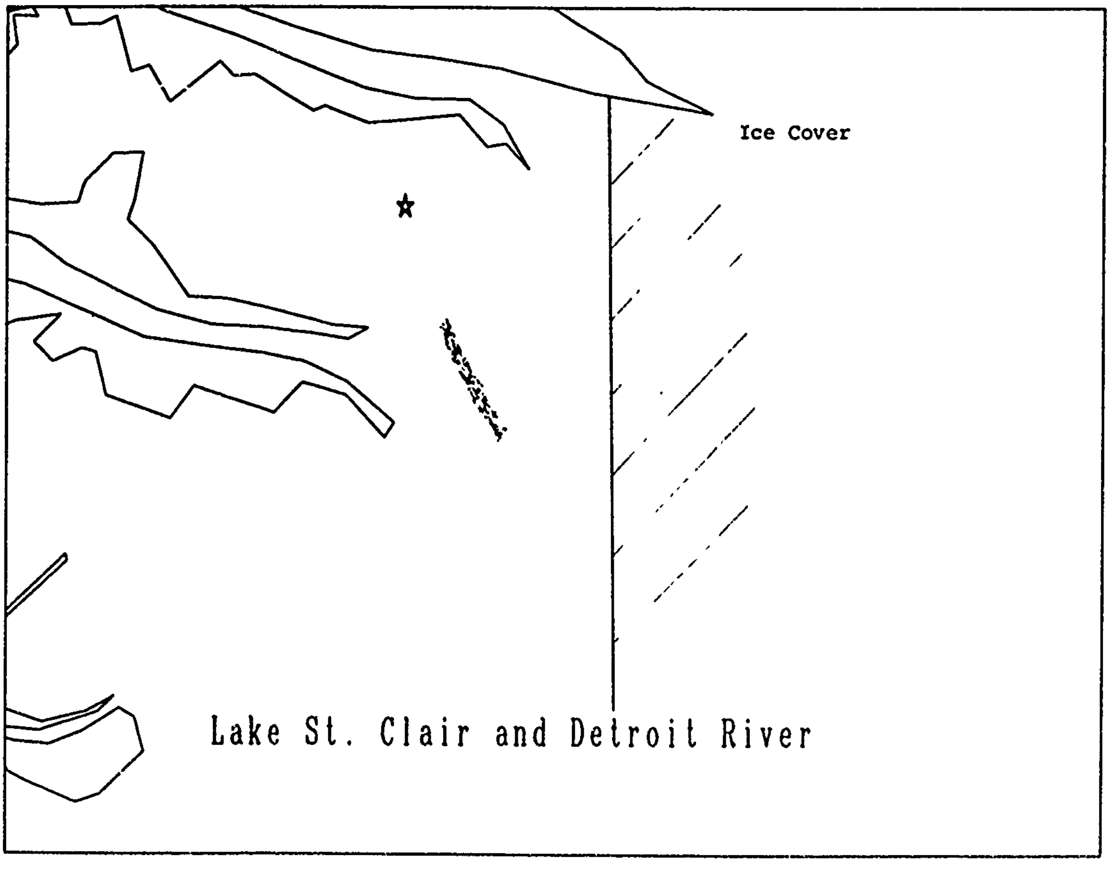
Slick information by pie / strip

Strip	Particles	-Le(ft)	X-mean	Le(ft)
27	66	-42.	0.	121.
28	51	-80.	0.	116.
29	65	-89.	0.	119.
30	54	-176.	0.	52.
31	68	-101.	0.	116.
32	56	-103.	0.	101.
33	68	-84.	0.	95.
34	66	-99.	0.	82.
35	5	-101.	0.	43.

Slick condition at the end of this time step

Fraction Evaporated = .14706
Amount Dissolved (gals) : This Step = 1.5688 Total = 9.2324

e. Spill information at t = 2 hr.



f. Plot of slick location corresponding to Figure C2e.

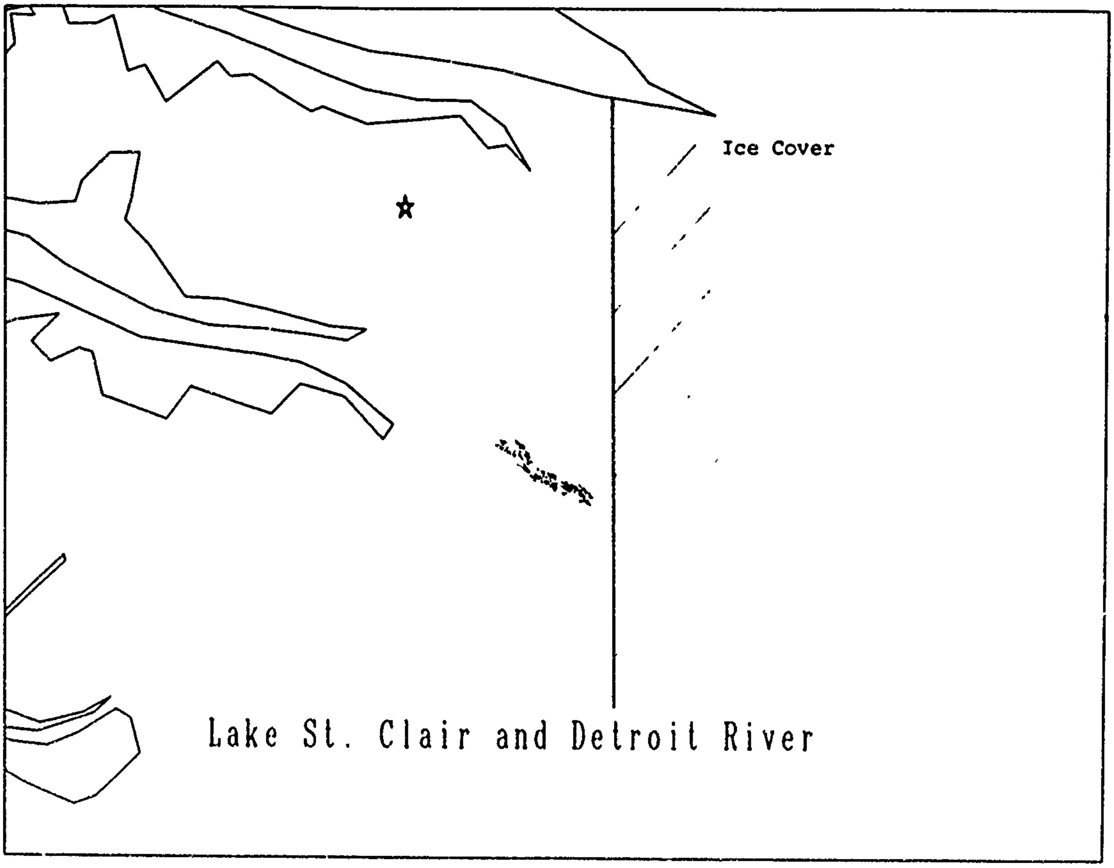
Figure C2 (cont'd).

```
Time =   3.00 Hrs -- Wind :mag=  4.0 mph, dir =  0.0 deg   -- Air Temp= 40.0 F
Spill center after advection= -86307., 43639. (ft)
Volume per particle          =  16.185 gals

     Slick condition during this time step

Slick information by pie / strip
```

Strip	Particles	-Le(ft)	Y-mean	Le(ft)
-47	21	-123.	0.	80.
-46	72	-124.	0.	73.
-45	77	-97.	0.	93.
-44	90	-117.	0.	99.
-43	70	-128.	0.	92.
-42	75	-118.	0.	196.
-41	58	-113.	0.	202.
-40	37	-66.	0.	96.

```
      Slick condition at the end of this time step

 Fraction Evaporated = .20031
 Amount Dissolved (gals)      : This Step = 1.4632     Total = 15.505
```

g. Spill information at t = 3 hr.

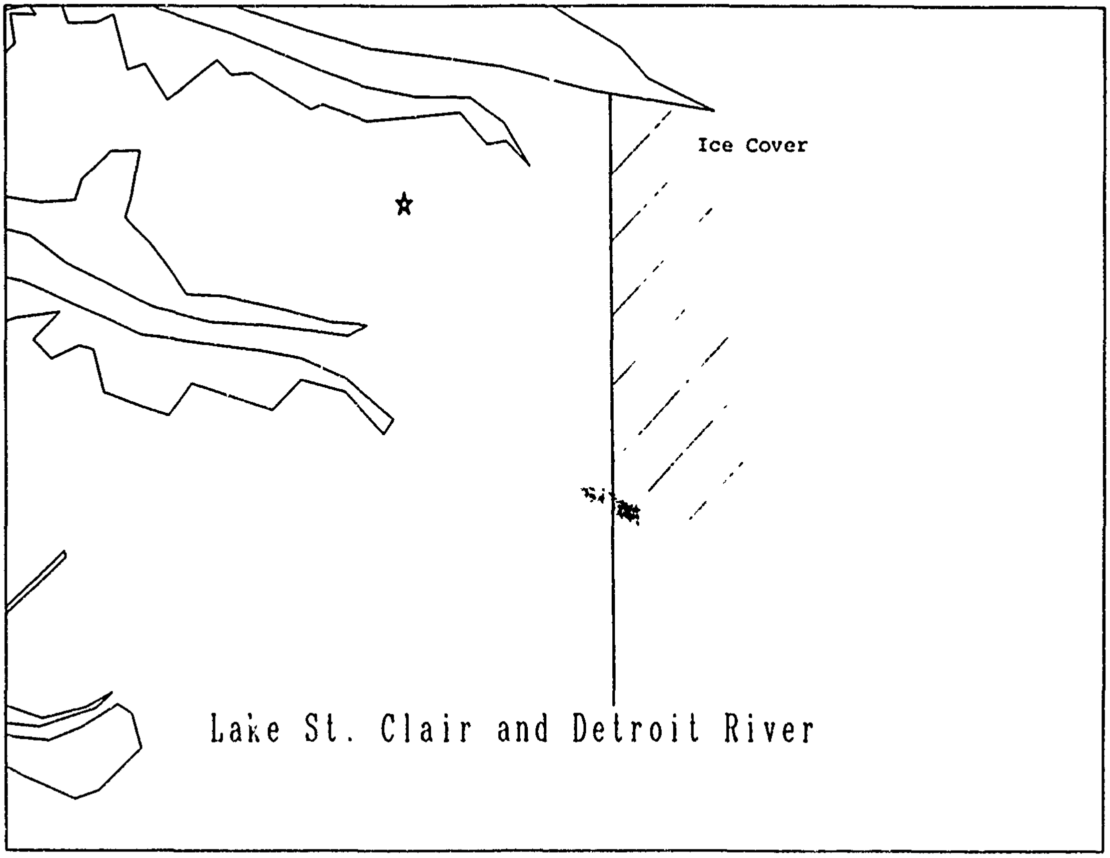


h. Plot of slick location corresponding to Figure C2g.

Figure C2 (cont'd).

```
Time =   4.00 Hrs -- Wind :mag=  4.0 mph, dir =  0.0 deg   -- Air Temp= 40.0 F
Spill center after advection= -83927., 42445. (ft)
Volume per particle          =  15.510 gals

     Slick condition during this time step

Slick information by pie / strip
Pie  No. of particles  Mean radius(ft)
 1         42             278.
 2         16             176.
 3         35             395.
 4        102             578.
 5         13             237.
 6         24             161.
 7         59             286.
 8        179             437.
      Slick condition at the end of this time step

 Fraction Evaporated = .22655
 Amount Dissolved (gals)       : This Step = .88386     Total = 20.118
```

i. Spill information at t = *4 hr.*

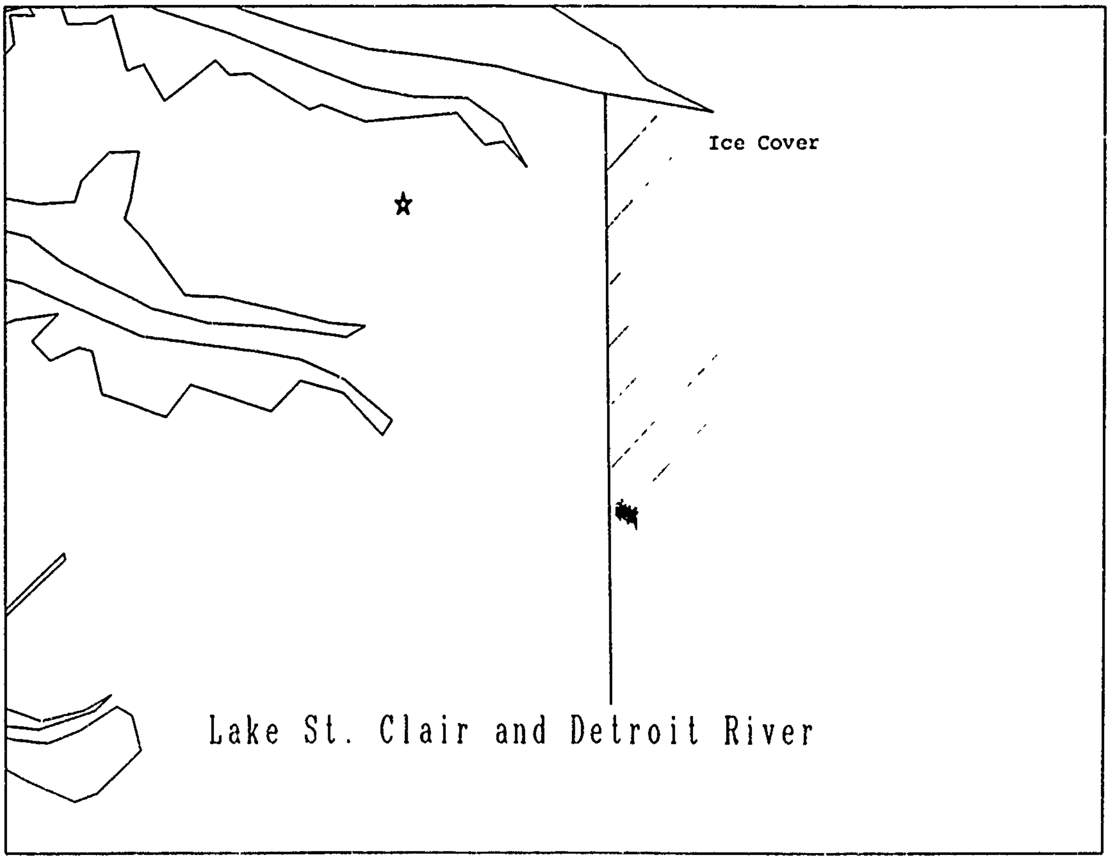


j. Plot of slick location corresponding to Figure C2i.

Figure C2 (cont'd).

```
Time =   5.00 Hrs -- Wind :mag=  4.0 mph, dir =  0.0 deg   -- Air Temp= 40.0 F
Spill center after advection= -83634., 42312. (ft)
Volume per particle         =  15.407 gals

     Slick condition during this time step

Slick information by pie / strip
Pie  No. of particles  Mean radius(ft)
 1         61             225.
 2         39             167.
 3         63             226.
 4         92             253.
 5         58             208.
 6         30             153.
 7         78             235.
 8         75             249.
       Slick condition at the end of this time step

 Fraction Evaporated = .22757
 Amount Dissolved (gals)       : This Step = .19960     Total = 21.146
```

k. Spill information at t = *5 hr.*

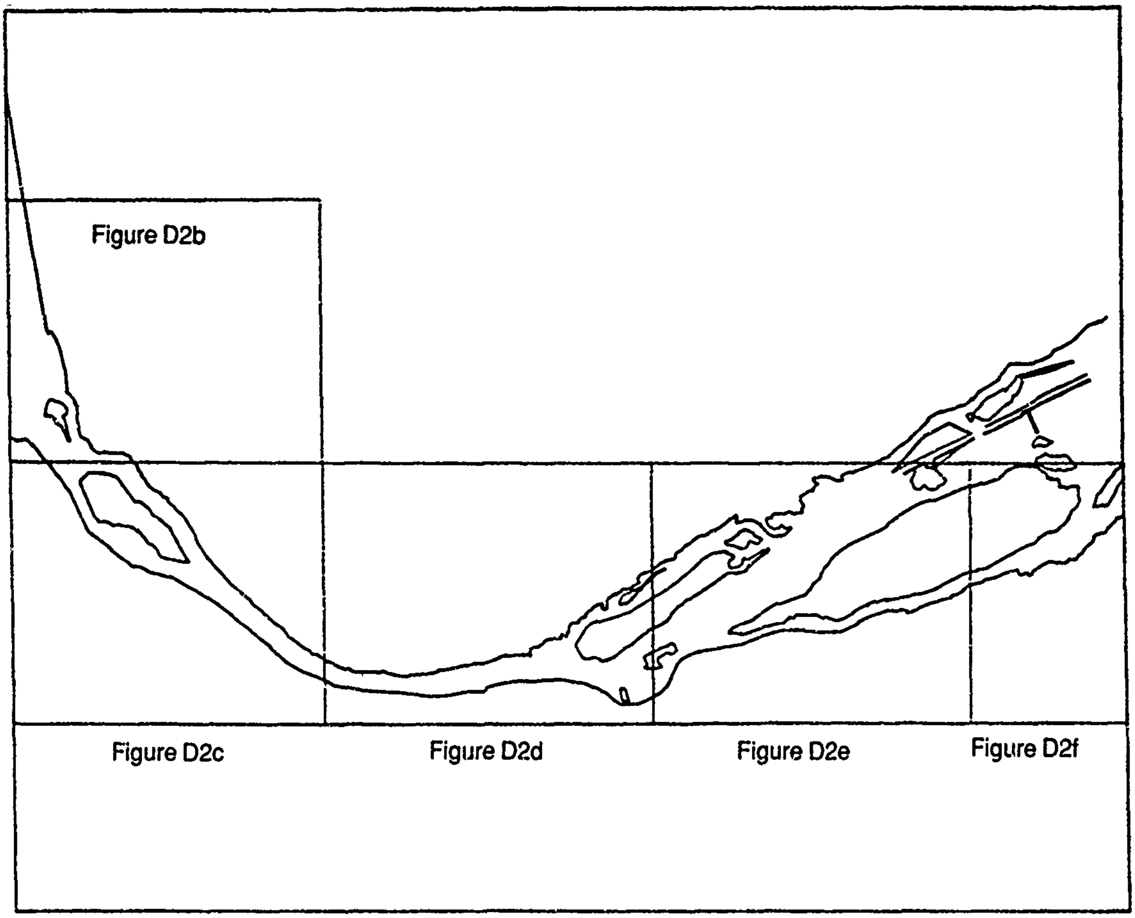


l. Plot of slick location corresponding to Figure C2k.

Figure C2 (cont'd).

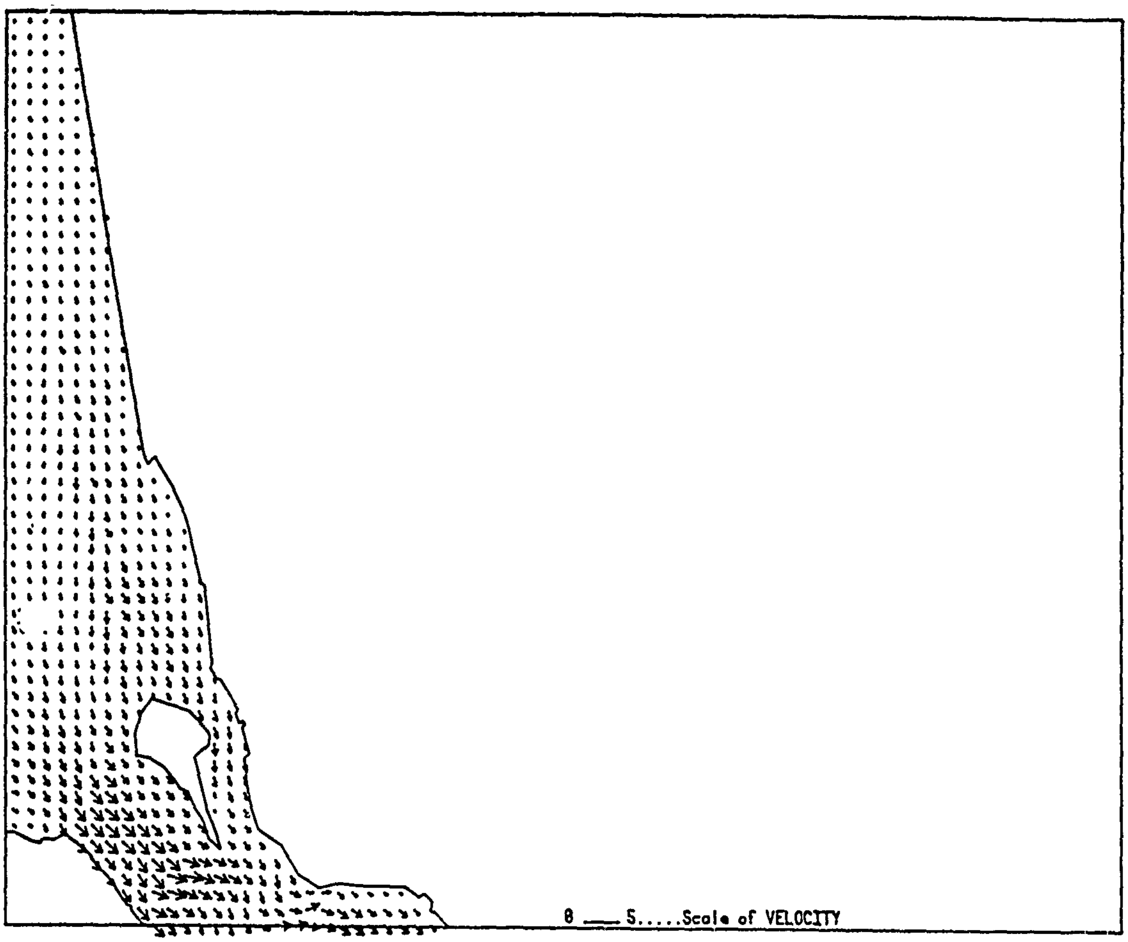
APPENDIX D. VELOCITY DISTRIBUTIONS IN LAKE ST. CLAIR AND THE DETROIT RIVER CORRESPONDING TO THE STAGE AND DISCHARGE SHOWN IN FIGURE C1B

Figure D1. Velocity distribution in Lake St. Clair.



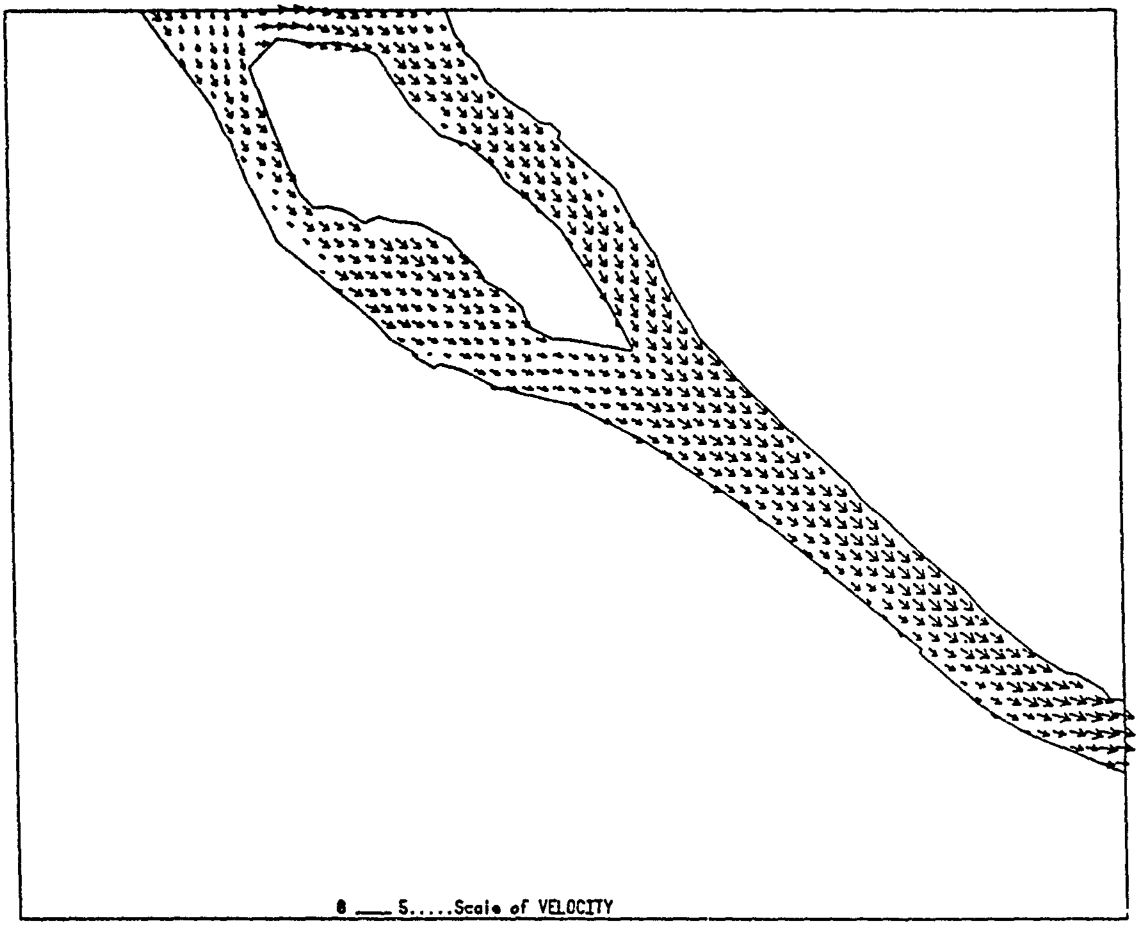
a. Index map.

Figure D2. Velocity distribution in the Detroit River



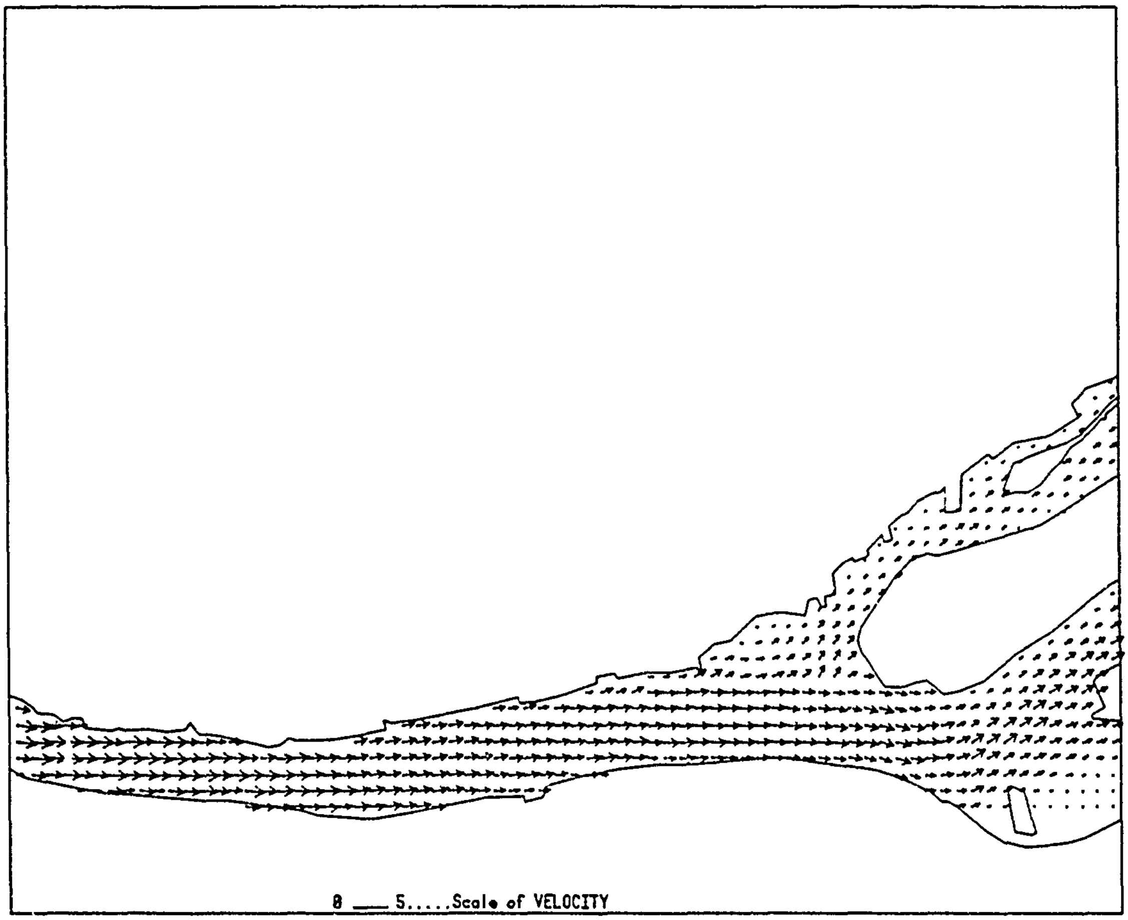
b. First section.

Figure D2 (cont'd).



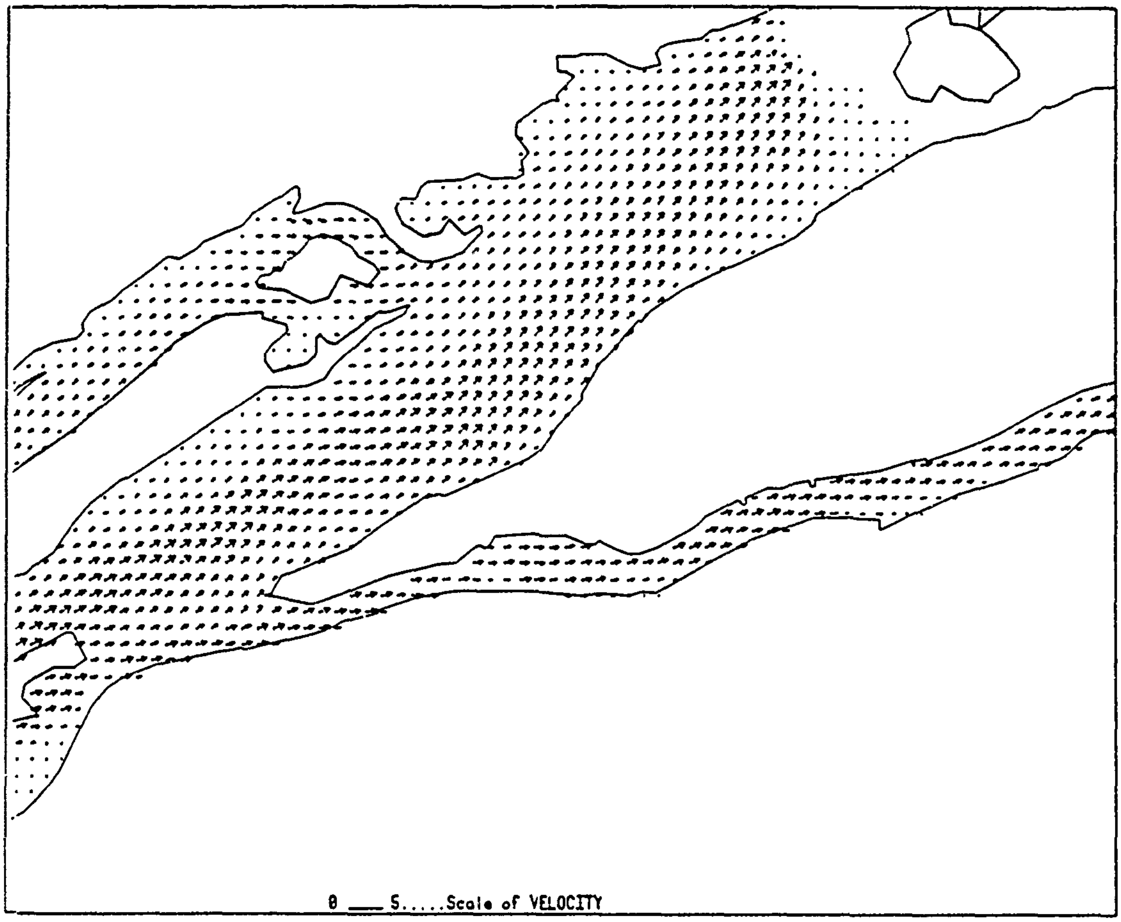
c. Second section.

Figure D2 (cont'd). Velocity distribution in the Detroit River.



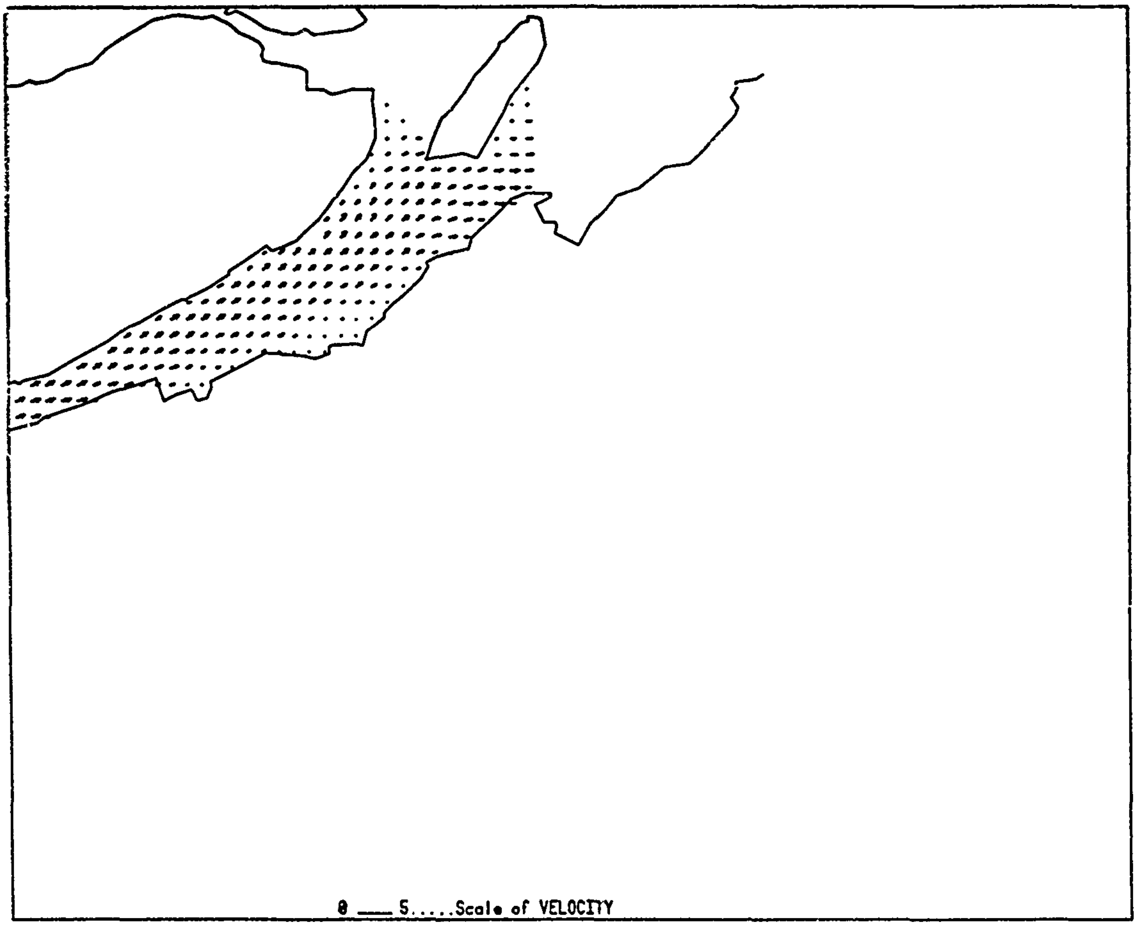
d. Third section.

Figure D2 (cont'd).



e. Fourth section.

Figure D 2(cont'd). Velocity distribution in the Detroit River.



f. Fifth section.

Figure D 2(cont'd).

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The growing concern over the impacts of oil spills on aquatic environments has led to the development of many computer models for simulating the transport and spreading of oil slicks in surface water. Almost all of these models were developed fo· coastal environments. In this study, two computer models, named ROSS and LROSS, were developed for simulating oil slick transport in rivers and lakes, respectively. This report explains how to use LROSS, the Lake–River Oil Spill Simulation model.

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